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TURBOJET ENGINE ANALYZER SYSTEM

W. J. HARRIS

The Garrett Corporation, AiResearch Manufacturing Company

TECHNICAL REPORT SEG-TR-67-44

JUNE 1969

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SEG-TR-67-44

TURBOJET ENGINE ANALYZER SYSTEM

W. J. HARRIS

FOREWORD

The hardware covered in this report was developed under USAF Project 3147, Task 314701, by AiResearch Manufacturing Company, a Division of The Garrett Corporation, 2525 West 190th Street, Torrance, California, in response to Purchase Request 120143, initiated by Aeronautical Systems Division, Air Force Systems Command, United States Air Force. This research and development program, for a Turbojet Engine Analyzer System, was conducted in compliance with Contract AF 33(657)11503 covering a time period of May 1963-July 1965.

The project was administered for Aeronautical Systems Division, Directorate of Propulsion and Power Subsystems Engineering, Deputy for Engineering by Hollis G. Zerkle, (ASNJD), who served as Air Force Project Engineer

This technical report has been reviewed and is approved.

Richard M. Ellis

Richard M. Ellis, Chief
Air Breathing Engine Branch
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Power Subsystems Engineering

ABSTRACT

This report describes Turbojet Engine Analyzer Systems as developed for application to J75-19W and J79-15 engines. Included are descriptions and design details of each major system component. The theory of operation, the modular breakdown, the self-test provisions, and the adjustments of the components are presented. Similar material is included on the System Ground Calibrator, a piece of ground support equipment.

The system is designed to monitor, analyze, and assess complete turbojet engine performance during ground and flight operations for the purpose of detecting required maintenance and diagnosing incipient or actual failures.

This abstract is subject to special export controls, and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Deputy of Engineering, Directorate of Propulsion & Power Subsystem Engineering, ASNJD, Wright-Patterson Air Force Base, Ohio.

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1.0 INTRODUCTION

The Turbojet Engine Analyzer System Program was initiated by U. S. Air Force Operational Support Requirement (OSR) 322 in July 1958. That document established the requirement for an Engine Analyzer System which was to upgrade the task of maintaining aircraft turbojet engines. The desired functions were (1) assessment of current engine condition, (2) diagnosis of malfunctions, and (3) prediction of next mission confidence and time until maintenance. It was recognized that achievement of these goals of assessment, diagnosis, and prediction would logically lead to achievement of the overall objectives of reduced maintenance costs, increased operational effectiveness, and improved flight safety.

The program has been characterized by an orderly development progression under USAF control. For a short period following the establishment of the OSR, various attempts were made to implement the requirement by the most simple, straightforward, obvious approaches. While these were valuable efforts, the results were insufficient, and in 1961 competition was held to select a contractor for a basic study program. Separate and parallel studies were awarded to The Garrett Corporation and to General Electric Company to determine the feasibility of the requirement and to establish the basic theory behind its implementation. Both studies were completed in mid-1962 and both concluded that the system was, in fact, feasible.

A major objective of the study program was to determine what engine parameters to measure, how and where to collect these data, how to rapidly and automatically interpret them, and, finally, how to present the evaluated results to Air Force maintenance personnel in optimum fashion. At this point, a second competition was held, resulting in the selection of The Garrett Corporation as the Phase II contractor. Beginning in April 1963, the study recommendations were implemented in a program including final hardware design, hardware fabrication, installation on two F-105D and two F-4C aircraft, finalization of digital computer programs, and conductance of a one-year flight test program and processing of test data.

This report describes the hardware utilized in Phase II of the program. A companion report, SEG-TR-67-45, presents the results of the flight test, evaluation of the engine analyzer systems and describes the development and application of data processing programs for analysis of engine analyzer data.

2.0 DISCUSSION

2.1 General

The Turbojet Engine Analyzer System is functionally represented in Figures 1 and 2. The system measures indicative engine operating parameters by means of the network of transducers, sensors, and switches. The signals from these devices are used for two purposes. The Computer/Display monitors certain of the parameters; if any of these operating conditions exceed predetermined limits, red flags are presented on the face of the Computer/Display to indicate this over-limit occurrence. The Signal Data Translator converts input analog signals into digital signals and sequentially feeds them to the Recorder, along with certain parameters calculated by the Computer/Display, and with documentary identification data, such as engine serial number and date. This documentary data is manually entered into the Engine Analyzer System by means of digital thumbwheels on the face of the Signal Data Translator. The recorder then produces a record on magnetic tape of the measured engine operating conditions throughout the flight. This tape recording can be processed by a digital computer facility using the Turbojet Engine Analyzer Data Processing Program to yield analyses of the health of the engine, its performance, and its efficiency, to find trends in the degradation of the health and performance of the engine, and to extrapolate these trends to predict future engine efficiency, performance, health, and life expectancy. Figure 3 is a block diagram of the data acquisition and processing system. Shown are the data, equipment, and steps involved in making an engine health assessment and diagnosis.

As evident from Figures 1 and 2, two Engine Analyzer Systems have been developed: One for J75-19W engines (F-105D aircraft) and one for J79-15 engines (F-4C aircraft). They will be referred to hereafter as the F-105D System and the F-4C System.

2.2 Description of F-105D System

The F-105D Engine Analyzer System comprises one Computer/Display, one Signal Data Translator, one Recorder, one set of transducers, and interconnecting cables, pneumatic lines, and connectors. A complete list of the transducers is given in Table I; the table also presents salient characteristics of the Engine Analyzer System including the part numbers, form-factor, and weight of each of the major system components. Table II presents the power requirements of the system components. Appendix I presents complete electrical circuitry schematic for the system components.

2.2.1 Transducers

The system includes a set of transducers which measure the temperatures, pressures, ON-OFF switch conditions, fuel flow, and speed (rpm) which indicate changes of the engine operating conditions. The transducers are of the following types:

1. Variable reluctance transducers
2. Position variable resistance transducers
3. Temperature variable resistance transducers
4. Pressure switches

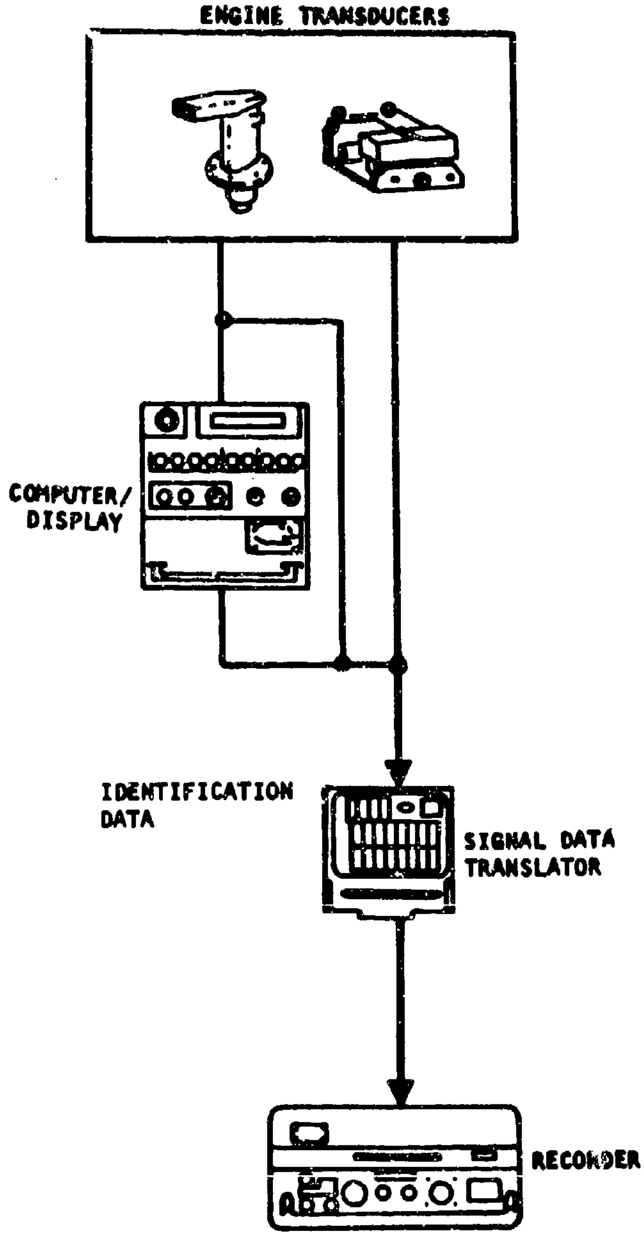

Figure 1. Engine Analyzer System Functional Block Diagram (J75-19W Engine)

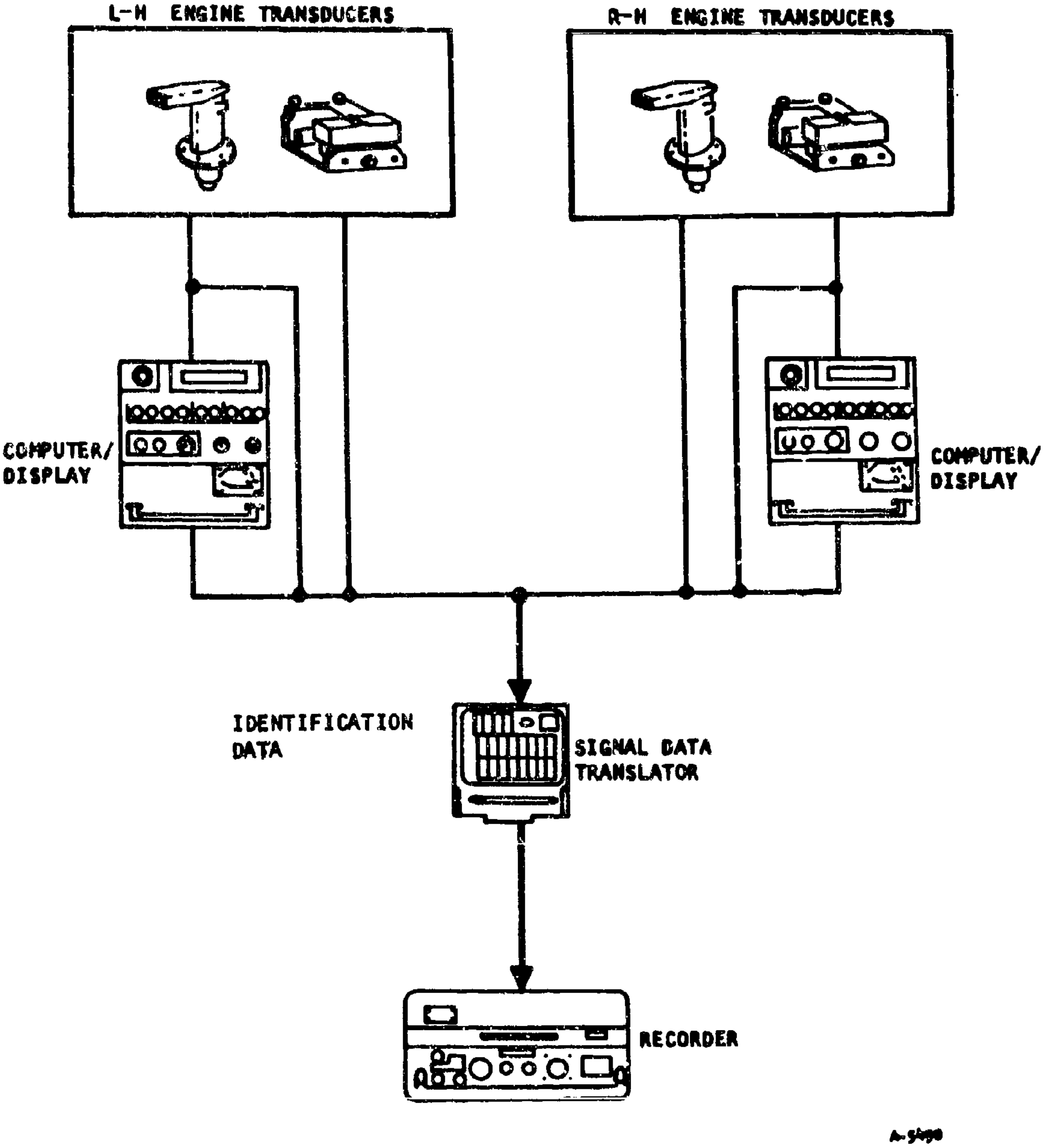

Figure 2. Turbojet Engine Analyzer System
Functional Block Diagram (J 79-15 Engine)

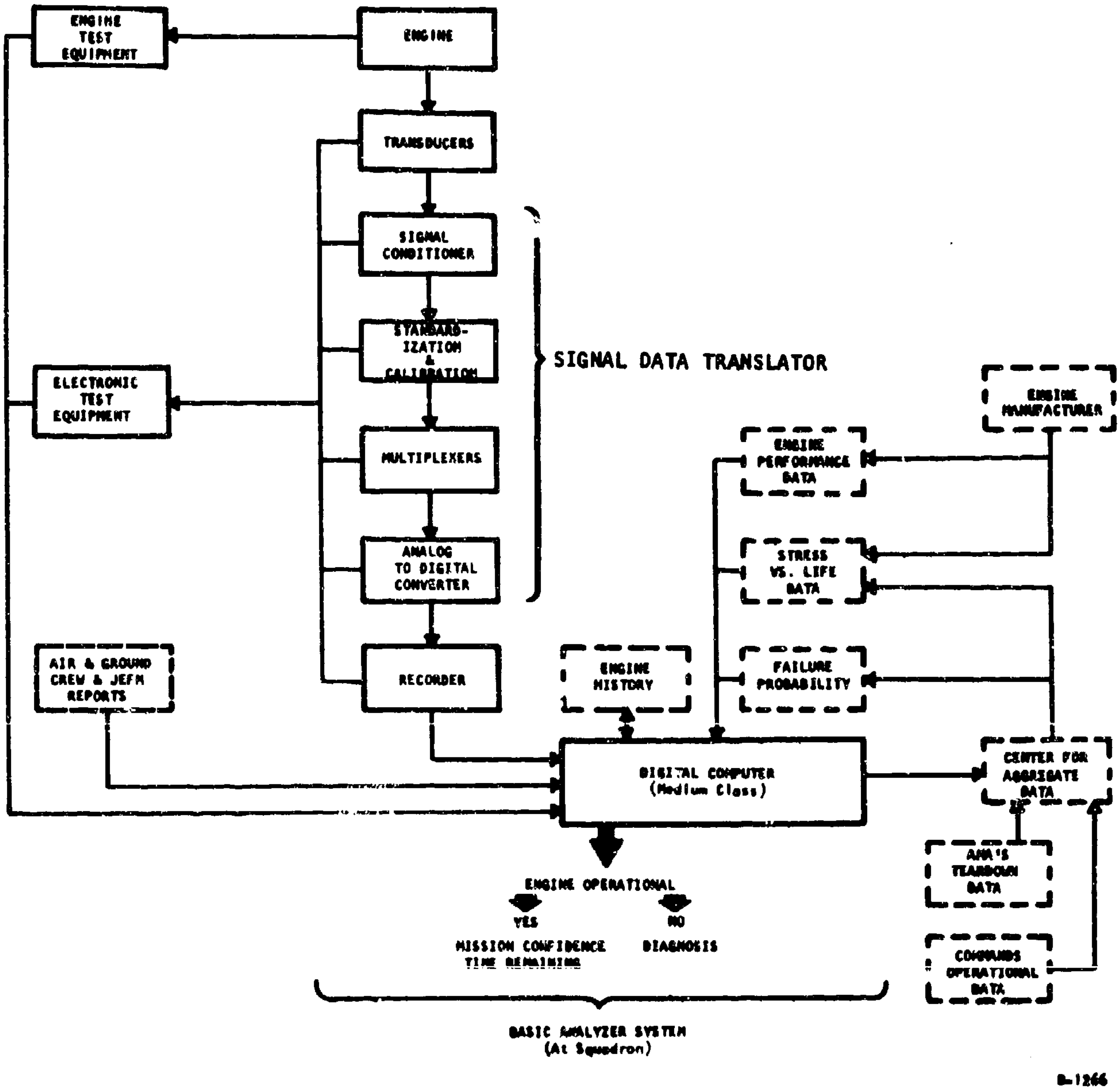

Figure 3. Data Acquisition and Processing Block Diagram

TABLE I

F-105D ENGINE ANALYZER SYSTEM DATA

System Components	Part Number	Size (Inches) height x width x depth	Weight (lb)
Computer/Display	538254-1-[illegible]	7 by 6.5 by 9.88	18.5
Signal Data Translator	538250-1-1	5.5 by 5.25 by 12.5	17.7
Recorder	538956	5 by 11 by 11	22.7^{Δ}
TRANSDUCERS			
Afterburner Switch*			
Anti-Ice Switch*			
Oil Breather Pressure	538967-2		
Compressor Discharge Pressure	538947-1		
Compressor Discharge Temperature	538952		
Compressor Inlet Pressure	538362-1-1		
Engine Pressure Ratio*	61-2484**		
Exhaust Gas Temperature Indicator	538380		
Fuel Flow Transducer*	61-2456**		
Ignition Switch*			
Oil Pressure Switch*			
Oil Pressure Transducer*	61-2479**		

*Engine analyzer system uses existing aircraft transducer or switch
**Air Force Equipment Reference Numbers (AFERNO)
Δ Includes tape and reels

TABLE I (Continued)

System Components	Part Number	Size (Inches) height x width x depth	Weight (lb)
Oil Temperature Switch	538948		
Oil Temperature Transducer	538950		
Power Lever Angle	538444-1-1		
Spool Speed (N_1 and N_2)*	61-8732**		
Inlet Total Temperature	60-1625**		
Water Injection Switch*			

*Engine analyzer system uses existing aircraft transducer or switch
**Air Force Equipment Reference Numbers (AERNO)

TABLE II

F-105D ENGINE ANALYZER SYSTEM POWER DATA

Computer Display 538254-1-1, S/N 46-R2 (All measurements made with nominal inputs of 115 v, 400 cps, and 28 v dc)				
	Quiescent (VA) (PF)	Slew (VA) (PF)	Self Test (VA) (PF)	
ØA Sec	36.8 0.75	37.4 0.75	35.7 0.75	
ØB Sec	7.3 0.78	7.3 0.78	7.3 0.78	Sustained
ØC Sec	7.3 0.78	7.3 0.78	7.3 0.78	
ØA PRI	10.2 0.80	9.2 0.80	9.2 0.80	Start-Up and Shut-Down
D-C PRI	6.5 w	9.8 w	9.8 w	
D-C Sec	14.0 w	16.8 w	25.5 w	

Signal Data Translator 538250-1-1, S/N 34-R2 (All measurements made with nominal input of 115 v, 400 cps)			
ØA Sec	12.7 VA	PF .9	
ØB Sec	10.4 VA	PF .9	Sustained
ØC Sec	10.7 VA	PF .9	

Recorder 538956, S/N 104 (All measurements made with nominal inputs of 115 v, 400 cps, and 28 v dc)		
115 v	ØA Sec	1.0 w
28 v dc Sec		32.0 w

EGT Indicator 54812 (not measured value). Powered with 400-cps power	
10 VA	Start-Up, Shut-Down and Sustained

5. Temperature switches

6. Indicators (EGT)

7. Tach-generators

8. Synchro output transducers (EPR, fuel flow)

9. Relay contacts and limit switches

A list of the transducers used in the F-105D Engine Analyzer System is included in Table I of this section. This table includes the weight and dimensions of major units, in addition to the applicable AiResearch part number or Air Force Equipment Reference Number (AERNO). The following paragraphs briefly describe the function of each transducer.

2.2.1.1 Afterburner (A/B) Switch

The afterburner signal to the Computer/Display and Signal Data Translator indicates that the A/B switch on the throttle (cockpit) has been activated. A complete description of the A/B system is found in Air Force Flight Manual T.O. IF-105D-1, page 1-15, and is shown in Figure 1-9 of that manual. The analyzer system is isolated from the aircraft afterburner system by an isolation relay.

2.2.1.2 Anti-Ice (A/I) Switch

The anti-ice signal indicates that the A/I switch in the cockpit has been activated. The Engine Analyzer System receives this signal from switch S-214 on the aircraft. The wiring diagram of the A/I system is found in Air Force technical manual T.O. IF-105D-2-12, page 1-84, Figure 1-21.

2.2.1.3 Breather System Pressure ($P_{oil\ b}$) Transducer

This transducer measures the absolute gas pressure in the oil tank, bearing sumps and N_2 gearbox. The transducer is a variable reluctance type with a range from 0 to 25 psia. The transducer output voltage varies from 0 to 500 mv at 400 cps for an input pressure change from 0 to 25 psia with a load of 20,000 ohms across the output.

2.2.1.4 Compressor Discharge Pressure (P_{cd}) Transducer

This transducer measures absolute pressure at the discharge of the compressor. The transducer is a variable reluctance type with a range from 0 to 310 psia. The transducer output voltage varies from 0 to 500 mv at 400 cps for an input pressure change from 0 to 310 psia with a load of 20,000 ohms across the output. The output signal is then supplied to the Signal Data Translator.

2.2.1.5 Compressor Discharge Temperature (T_{cd}) Transducer

The compressor discharge temperature transducer is a variable resistance element made of platinum wire, and has a temperature range of -100°C to +500°C with a nominal resistance of 50 ohms at 0°C. The probe tip has an applied operating pressure of 0 to 500 psia.

2.2.1.6 Compressor Inlet Pressure (P_{t_2}) Transducer

The compressor inlet pressure transducer utilizes a servoed force-balance sensor and provides output voltages proportional to the natural logarithm of absolute pressure, switching action occurring at certain time-rates-of-change of the logarithm of absolute pressure, and a voltage proportional to absolute pressure.

2.2.1.7 Engine Pressure Ratio (EPR) Transducer

The EPR transducer is a pressure ratio synchro-style thrust transmitter type MK-2). Dual outputs are provided as follows from one synchro to:

a. An indicator with a range of 1.2 to 3.4 units (type MR-1) in the cockpit

b. An input to the SDT Scott "T" transformer

2.2.1.8 Exhaust Gas Temperature (EGT) Transducer

The exhaust gas temperature system consists of existing Chromel-Alumel thermocouple probes in the engine that actuate a single-point null-balancing type indicator in the cockpit. The indicator in turn provides four output signals to the engine analyzer. The four outputs are two potentiometers (pots) and two switches: switch "A" closes at 752°F (400°C) for hot start and switch "B" closes at 1300°F (704°C) for in-flight overtemperature; pot "1" is a log function of EGT and pot "2" is exponential function of EGT.

2.2.1.9 Fuel Flow (W_f) Transducer

The fuel flow transducer is a remote indicating synchro-style rate of flow transmitter (type MA-1). The synchro outputs feed the following:

a. An indicator with a range of 400 to 24,000 pph (type MA-2) in the cockpit

b. A resolver in the C/D fuel flow servo

2.2.1.10 Ignition Switch

The ignition switch signal is obtained from a slave relay on the aircraft (K-9) located in relay box A-5. The complete wiring diagram of the aircraft ignition system is found in Air Force T.O. 1F-105D-2-12, page 1-89, Figure 1-25A.

2.2.1.11 Oil Pressure Switch

The oil pressure switch is a differential-pressure-actuated switch used as a warning device to indicate the loss of turbine engine lubricating oil pressure. The switch provides a ground signal to the Computer/Display upon loss of oil pressure.

The pressure switch has a pressure and vent port and is actuated by the pressure differential between ports. When oil pressure is above 38 (+0,-3) psid, a diaphragm in the switch housing maintains the switch contacts in the open position. When booster-pump pressure drops to 31 (±1) psi and below, the diaphragm closes the switch contacts, providing a ground circuit to the master caution control box. The pressure switch operates as follows: on increasing differential pressure, the switch will open the circuit at 38 (+0,-3) psid and on decreasing differential pressure the switch will close at 31 (±1) psid.

2.2.1.12 Oil Pressure (P_{oil}) Transducer

The oil pressure transducer is a variable reluctance pressure transmitter (TRU-20/A). The output signals are supplied to an indicator (type MO-2) in the cockpit and to the Signal Data Translator.

The TRU-20/A is a variable reluctance type transmitter having only one moving part, the armature that moves axially through a pair of fixed hermetically sealed coils. Oil and breather pressure entering the transmitter through their respective ports act against diaphragms connected at each end of the armature shaft. When the oil pump is operating, the axial travel of the armature will be in the direction of the lesser pressure; thus, the values measured by the transmitter will actually be the differential pressure between the oil pump output pressure and the breather pressure. As engine oil pressure enters the transmitter it deflects the diaphragm, thus changing the position of the armature relative to the flux air gaps. This action changes the relative inductance values in the two halves of the transmitter coil causing a change in voltage at the center tap of the indicator. The oil-pressure transmitter is mounted on the left side of the engine on the accessory gearbox and is accessible through Access Door FF-101.

In some aircraft, the MH-5 synchro output transmitters are used.

2.2.1.13 Oil Temperature Switch

The oil temperature switch is a temperature actuated switch used for indicating excessive oil temperature on the aircraft engine in flight. The switch provides a ground signal to the Computer/Display upon excessive temperature conditions

2.2.1.14 Oil Temperature (T_{oil}) Transducer

The oil temperature transducer is a clamp-on and adhesive bonded temperature transducer used for measuring the oil temperature of the aircraft engine in flight The transducer output is a variable resistance signal supplied to the Signal Data Translator.

2.2.1.15 Power Lever Angle (PLA) Transducer

The power lever angle transducer is a single turn precision linear variable resistor. The output goes to the signal data translator.

2.2.1.16 Spool Speed (N_1) Transducer

The spool speed transducer N_1 is a miniature electric three-phase, two-pole a-c tachometer-generator (GEU-7/A).

NOTE: While provisions were made for measuring this parameter, the tachometer pads were deactivated on the J-75 engines.

2.2.1.17 Spool Speed (N_2) Transducer

The spool speed transducer N_2 is a miniature electric two-pole, three phase a-c tachometer-generator (GEU-7/A). The output signal goes to Computer/Display and the cockpit indicator, type ERU-5/A.

2.2.1.18 Total Temperature (T_2) Transducer

The total temperature transducer is a dual element total temperature probe capable of operating during atmospheric icing conditions. The dual elements are platinum wire, temperature-variable resistors which have a nominal resistance of 50 ohms at $0^{\circ}C$. The standard F-105D temperature probe (single element) is replaced with a dual element probe; the extra element is used for the engine analyzer system.

2.2.1.19 Water Injection (WI) Switch

The water injection signal indicates that the water injection switch in the cockpit has been activated.

2.2.2 Computer/Display

The Computer/Display is a major component of the Engine Analyzer System. This unit, shown in Figure 4, is located on the F-105D in the CIN compartment.

The Computer/Display presents red-flag indications when any of several engine parameters exceed predetermined limits. The flags, once tripped, hold the indication magnetically until they are manually reset by a ground crewman. The device also presents an accumulated total of the engine operating hours, and of the hot section growth factors (a function of engine time and temperature). In addition to this data presentation, the Computer/Display provides some of the data recorded in flight.

The front face of the Computer/Display is shown in Figure 5. The indicators are grouped according to parameter, as shown in the figure. The controls in the top row on the Computer/Display are the calibration adjustments and the self-test switch. The calibration adjustments, which are normally covered by a shield to prevent any accidental change in adjustment, are used to adjust the Computer/Display for engine-to-engine variations. The self-test provided is a two-level check of the flag displays. The calibration adjustments and self-test are covered in detail later in this section. The history card on the front of the Computer/Display shows the correction used for finding true engine operating time. Instructions for its use are given on the card.

2.2.2.1 Computer/Display Theory of Operation

a. Summary - The Computer/Display mechanizes test cell and thermodynamic performance parameters to provide a go/no-go assessment at shutdown of gross engine health. The tests are:

1. Starting and stopping
    a. Hot start
    b. Slow start
    c. Fast stop
2. Steady-state engine performance
    a. Referred fuel flow
    b. Engine temperature ratio
3. Maximum limit parameters
    a. High EGT
    b. Engine overspeed: High and maximum

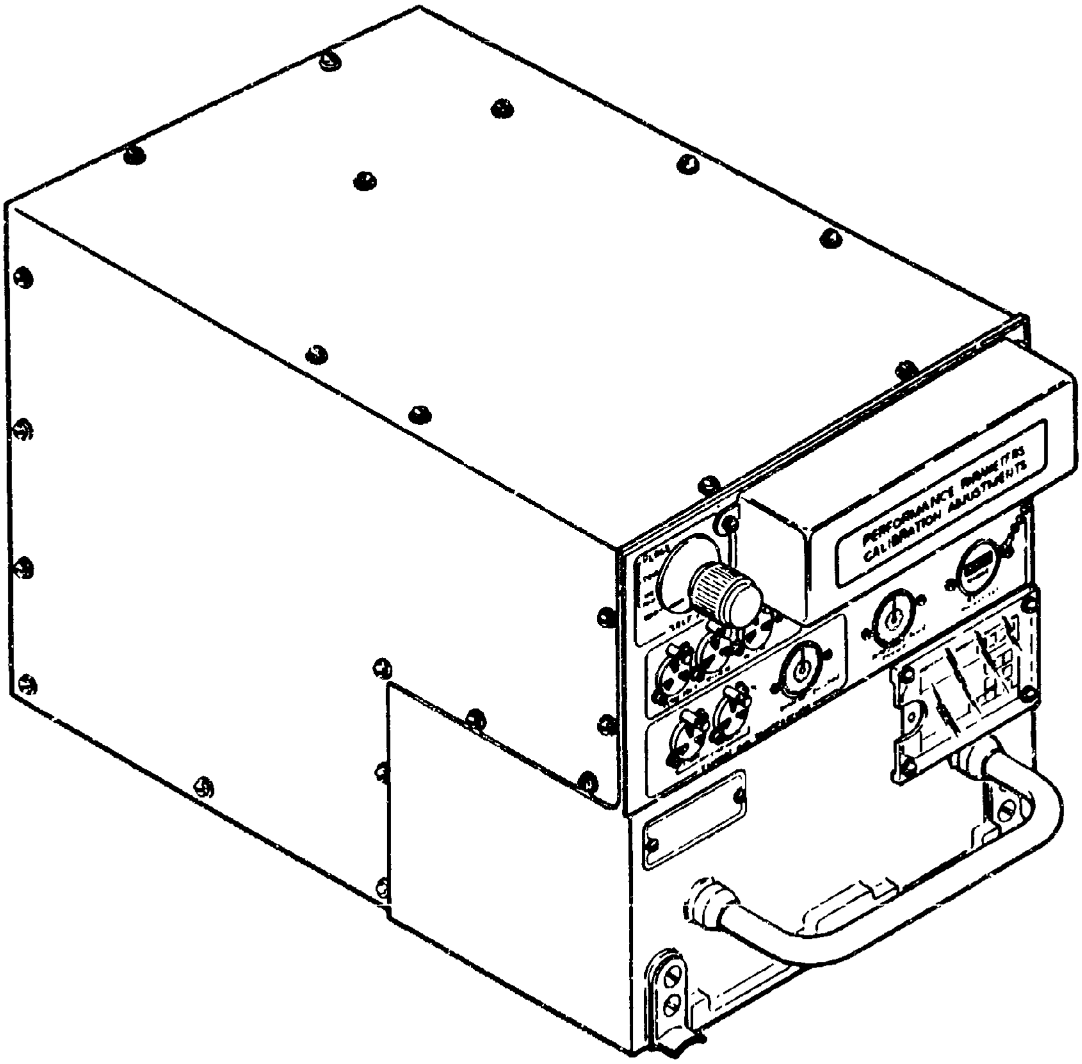

Figure 4. Engine Analyzer System Computer/Display

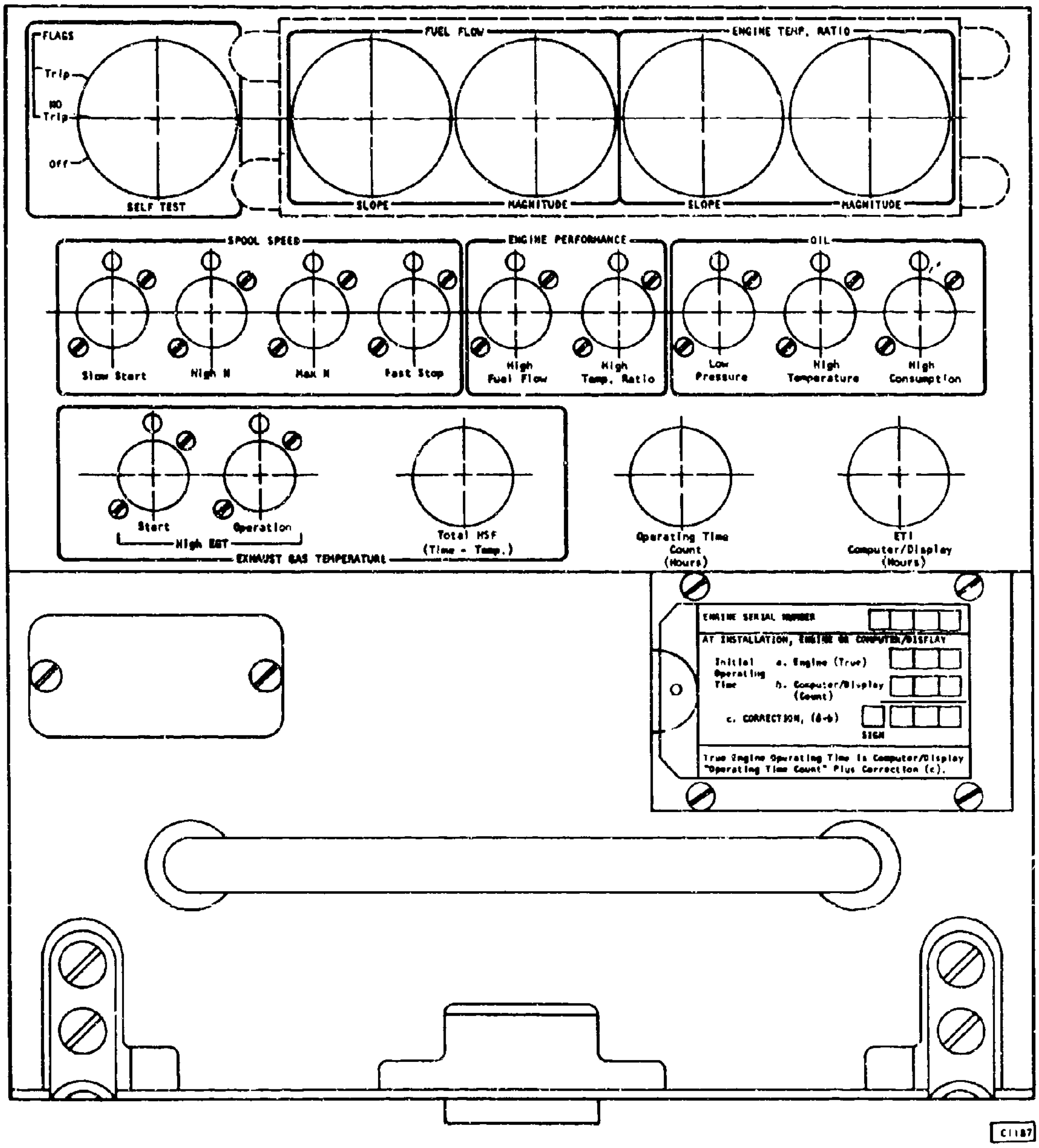

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Figure 5. Computer/Display Face

c. Low oil pressure

d. High oil temperature

4. Expended hot section factors

5. Time Data

a. Engine time since overhaul

b. Elapsed time indication

Since the object of the Computer/Display is to assess gross health rather than perform engine diagnosis, it considers the engine in its entirety rather than its component parts. Table III shows the performance, mechanical, and maximum-limit parameters assessed during flight and their test conditions and limits.

The Computer/Display contains all of the signal conditioning required to make it an autonomous unit from the Signal Data Translator and Recorder.

Performance Parameter Checks - The Computer/Display continually compares measured values of fuel flow and EGT ratio against specified performance to assess whether the engine is working within tolerances. The computations are standardized to sea-level conditions and corrected for Reynolds number effects.

Maximum Limit Checks - Maximum limits exist and are mechanized for exhaust gas temperature, spool speed, starting time, and coastdown time.

Mechanical Parameters - The mechanical parameters checked by the Computer/Display are oil pressure, and oil temperature. Provision for a mechanization of a check on oil consumption at a later date is also included in the Computer/Display.

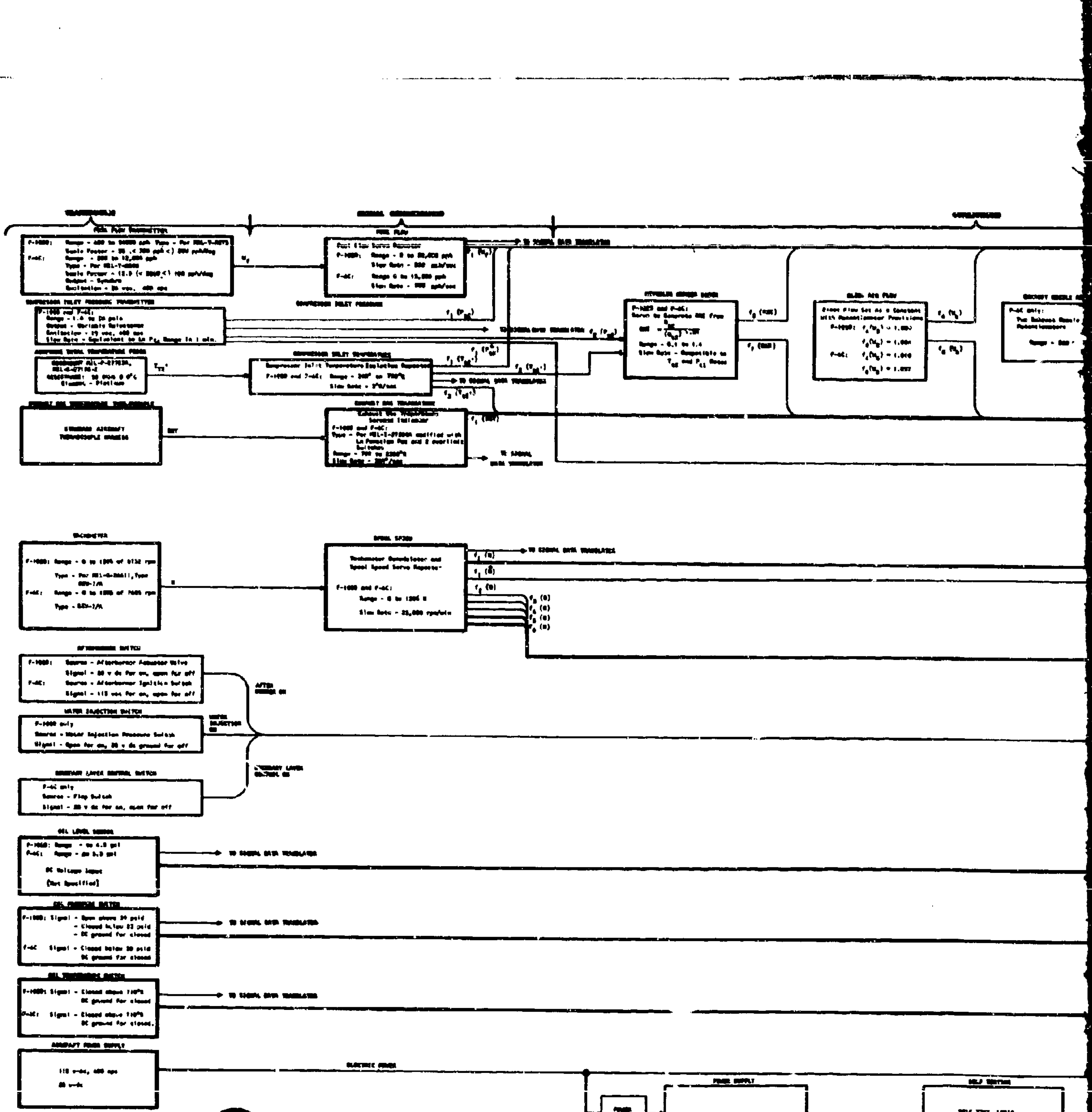
Signal Flow Diagram - A signal flow diagram of the Computer/Display is presented as Figure 6. This chart graphically illustrates the operation of the unit. The inputs are shown with the ranges of the input devices, the scale factors, and applicable military specifications. The signal conditioning which is performed on each input and the uses of each input are also indicateed on the chart. The signals required for each of the reference parameters are shown, as well as a tabulation of the equations, and the trip points of each of the flags.

Study of this signal flow diagram provides a working knowledge of the operation theory of the Computer/Display. The chart indicates which of the engine operating parameters affect which flags and the point at which each flag should trip.

TABLE III

COMPUTER/DISPLAY FLAG CHARACTERISTICS

Test	Test Condition	Failure Trigger Level
1. Slow Start	Engine starting cycle from ignition or 10% rpm to 50% rpm. Locked out thereafter	Greater than 40 sec
2. Fast Stop	Engine shutdown 50% to 10% rpm	Less than 25 sec
3. Referred Fuel Flow	Steady-state engine operation, non-afterburning, non-water injection operation	$W'_{f\ meas} - W'_{f\ ref} > .10\ W'_{f\ ref}$
4. Engine Temperature Ratio	Steady-state engine operation, non-afterburning, non-water injection operation	$ETR_{meas} - ETR_{ref} > .06\ ETR_{ref}$
5. High EGT		
a. Hot Start	Engine starting cycle to 50% rpm. Locked out thereafter	Greater than 400°C (Thermocouple time constant prevailing)
b. Observation	Sustained engine operation	Greater than 704°C
6. Engine overspeed		
a. Maximum	Any condition	Greater than 108% N_2
b. Normal	Any condition	Greater than 106.5% N_2
7. Low Oil Pressure	N_2 greater than 90%	Less than 31 psid
8. High Oil Temperature	Any condition	Greater than 121°C
9. Expended Hot Section Factors	EGT greater than 1572°R (600°C)	Accumulation



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Los Angeles, California

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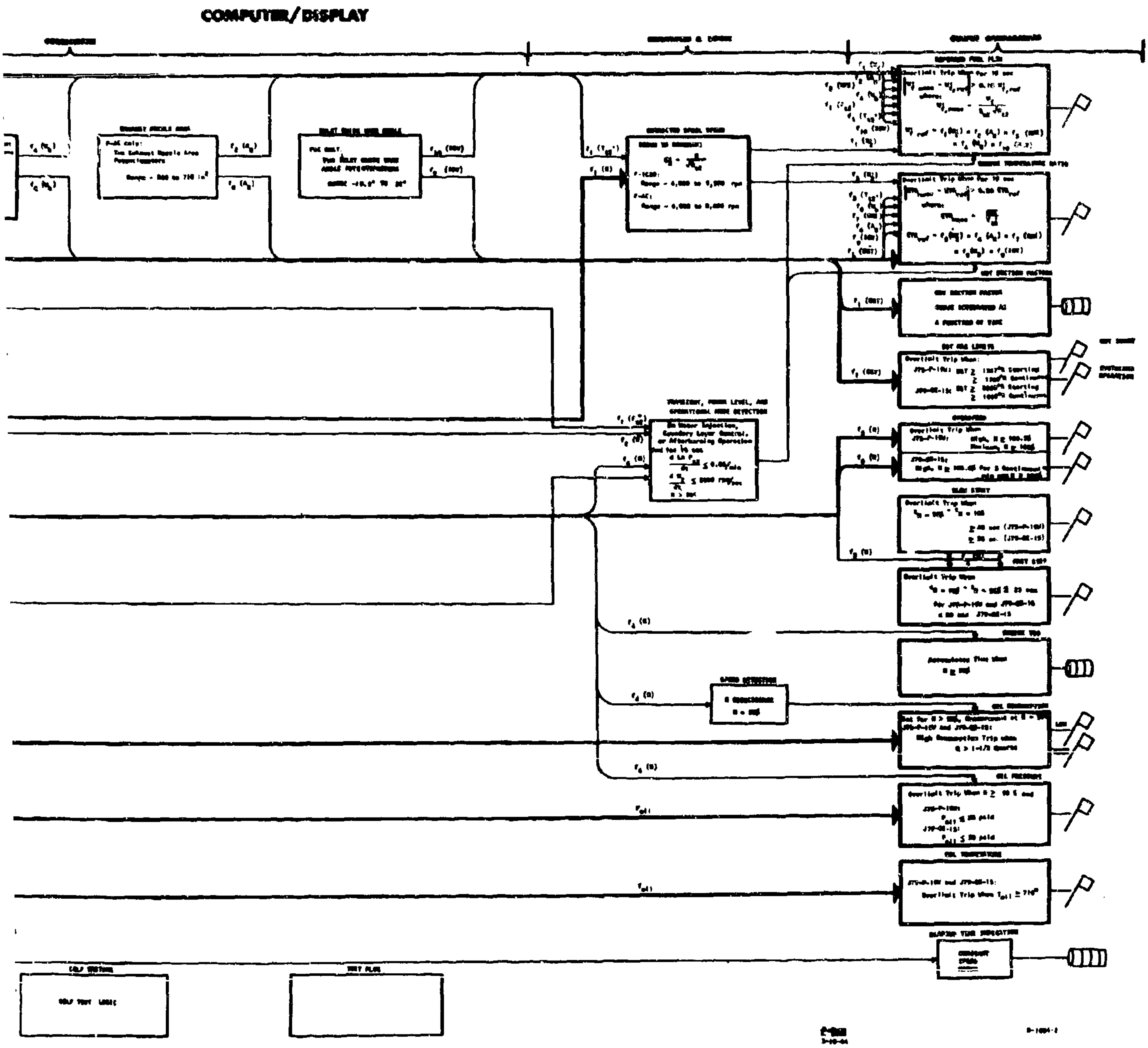

Figure 6. Computer/Display Signal Flow Diagram

B

b. Transient Engine Performance - Three tests are dependent on engine starting and stopping characteristics. They are:

1. Hot start

2. Slow start

3. Fast stop

These parameters are monitored under all starting conditions.

Hot Start - Hot start is monitored in the Computer/Display by replacing the standard EGT indicator in the F-105D with a modified MIL-I-2729A servoed indicator. The modification consists of addition of two switches and two potentiometers to the servo shaft. The switches are set at 400°C and 704°C, and adjustable ±111°C.

The 400°C switch is used to signal high starting exhaust gas temperature. The 704°C switch signals high operating EGT. One of the potentiometers provides the hot section factors signal to the Computer/Display. This function is discussed later in this section. The other potentiometer supplies the log function of EFT to the Computer/Display.

The 400°C starting limit, which was obtained from the F-105D Flight Manual, T.O. 1F-105D-1 dated 15 July 1952, appears low at first glance; this, however, is due to the thermal lag associated with the thermocouples.

For spool speeds less than 50 percent, the hot start switch is connected directly to the high start EGT flag. Should this switch close under these conditions, this flag will drop.

Location of the switches in the EGT indicator assures that all hot starts are monitored under any condition.

Slow Start - Slow start is detected by monitoring the time it takes for the engine to accelerate from 10 percent (or ignition) to 50 percent rpm. The limit for the slow start measurement is 40 sec, which was obtained from Pratt and Whitney Engine Specification A-2637A dated 15 July 1952

Fast Stop - Fast stop is monitored in the Computer/Display by clocking the time it requires for the engine to slow down from 50 percent to 10 percent rpm. A failure trip will occur whenever the time required for the engine to stop is less than 25 seconds. An interval adjustment provides for changes ±25 percent. This adjustment is not accessible from the Computer/Display front face, which precludes ground maintenance personnel from inadvertantly resetting them.

Cutting off the speed measurement at 10 percent is to eliminate the effects of windmilling, and engine reaction caused by local wind conditions.

c. Steady-State Engine Performance - Steady-state engine performance tests are made for the two referred engine parameters, fuel flow and engine temperature ratio. These tests are predicated upon the thermodynamic properties of the engine as it acts as a hot gas generator.

Steady-State Criteria - Limits for the steady-state engine performance detection have been set by reference to significant transient conditions such as engine start, engine acceleration, and aircraft climb at constant Mach number.

Aircraft climb less than 20,000 ft/min at sea level is a conservative estimate of engine steady-state performance. The simplest and most accurate method of detecting this condition is through monitoring of compressor inlet total pressure rate. The Computer/Display mechanizes Ln P_{t_2} rate, or $\frac{d \text{ Ln } P_{t_2}}{dt}$ and is set at 0.06 log units per minute. Whenever the absolute value of the rate exceeds this limit, the Computer/Display is locked out to assure that a false trip of the failure flags does not occur.

Engine acceleration is the rate of change of spool speed. In the Computer/Display, the spool speed rate is based on the amount of energy that is required to accelerate the spool. The threshold is set at a conservative 2000 rpm/min. When the N_2 rate exceeds this value, the Computer/Display is locked out.

A 90-percent spool-speed lockout is also incorporated in the Computer/Display. The 90-percent and higher power settings are the areas where engine data is significant due to higher stressing and operational design for this area.

Standardization and Correction - The first Computer/Display operation is to reduce the parameter measurements at speed and altitude to standard sea level conditions. The necessary pressure and temperature corrections are computed from inlet pressure (P_{t_2}) and temperature (T'_{t_2}).

Fuel flow and exhaust gas temperature are both influenced by Reynolds number effects that become significant when operating above 30,000 ft at low to moderate speeds. The necessary corrections are computed from P_{t_2} and T_{t_2}.

Water injection operation requires that the thermodynamic performance parameters of the Computer/Display be locked out. Although P_{t_2} transient detection at takeoff (water injection is used from takeoff to 8000 ft maximum) will lock the Computer/Display out in most cases, it may not lock it out at the beginning of takeoff roll where P_{t_2} rate is low. To assure optimum Computer/Display performance without false flag trips, a water injection lockout is provided. The signal comes directly from the water injection pressure switch on the water injection caution light circuit. The comparison is locked out until water injection ceases.

Engine fuel flow and exhaust gas temperature also depend upon the exhaust nozzle area. The J75-P-19W has a two-position nozzle that has a small area for normal operations and a large area for afterburner operations. The correlation between effective nozzle areas and measured nozzle area is extremely poor during afterburning operation. As a result it is impo: 'ble to adequately correct the fuel flow and engine temperature ratio compu...ions during this mode. To preclude false trips of the fuel flow and ETR flags, the comparison is deactivated during afterburning.

Steady-State Performance Parameter Computations - For steady-state engine operations, the Computer/Display continuously compares measured values of engine temperature ratio and referred fuel flow with that scheduled as a function of referred engine spool speed when corrected for bleed losses and Reynolds number. The steady-state logic previously described deactivates the computations when transients are encountered. Steady-state conditions must be held for 10 seconds (nominal) for engine to stabilize before the computation is reactivated. Deactivation of the comparison test occurs in less than 4 seconds when transient conditions are encountered.

The measured fuel flow and engine temperature ratio must exceed their reference limits for a minimum of 10 seconds before a failure flag will trip.

Variations from engine to engine within a given class can cause the N_2 reference curve to shift. To allow for variations in transducers and installed engine characteristics, two calibration adjustments are provided to allow offset of the curve in slope and in displacement by 10 percent. Independent adjustments are maintained for the two offsets.

Data for the reference computations was derived from AFSC F-105D Category II Performance and Stability Tests TDR 61-47, March 1962, Appendix 3.

The referred fuel flow over-limit flag triggers when

$$W_f'{}_{meas} - W_f'{}_{ref} \geq 0.10\, W_f'{}_{ref}$$

where $W_f'{}_{ref}$ is determined from the following computation

$W_f'{}_{ref} = f_1(N_2') \times f_3(RNI) \times f_4(W_b)$ and is computed by the Computer/Display. $W_f'{}_{meas} = \dfrac{W_f}{\delta_{t_2}\sqrt{\theta_{t_2}}}$ and is also computed by the Computer/Display.

Table IV gives inputs, function range, and slew rates of parameters for the referred fuel flow computation.

The engine temperature ratio over-limit flag triggers when

$$ETR_{meas} - ETR_{ref} \geq 0.06\, ETR_{ref}$$

TABLE IV

J75-P-19W/F-105D REFERRED FUEL FLOW COMPUTER/DISPLAY INPUTS, FUNCTION RANGES AND SLEW RATES

Input	Function	Source	Range	Slew Rate	Scale Factor
W_f	---	Fuel flow transmitter, Type MA-1 per MIL-T-8275	400 to 24,000 pph	NA	Synchro-- 25 pph/deg to 6K pph 200 pph/deg above 6K pph
T'_{t_2}	---	Airframe total temperature probe, Rosemont MIL-P-27723A, MIL-S-27186-2	390°R (-57°C) to 1100°R (338°C)	NA	Platinum wire with 50 Ω resistance at 0°C
N_2	---	Aircraft tachometer per MIL-G-26611 Type GEU-7A	0 to 120 percent of N_2	NA	
---	W_f	Computer/Display servo repeater	0 to 20,000 pph	2000 pph/sec	
---	$T_{t_2^1}$	Computer/Display isolation transformer	390°R (-57°C) to 1100°R (338°C)	3°R/sec	
P_{t_2}	---	Force-balance pressure transducer	1.6 to 36 psia	Equivalent to Ln P_{t_2} rate range in 1 minute	
---	N_2	Computer/Display servo repeater	0 to 120 percent N_2	25,000 rpm/min	
---	$N_2^{\frac{1}{2}}$	Computer/Display $N_2^{\frac{1}{2}}$ servo repeater	6000 to 9500 rpm	Compatible to N_2 and $T_{t_2^1}$ rates	
---	RNI	Computer/Display RNI servo	0 to 0.6	Compatible to P_{t_2} and $T_{t_2^1}$ rates	

where

$$ETR_{ref} = f_9(N_2) \times f_7(RNI) \times f_8(W_b)$$

and

$$ETR_{meas} = \frac{EGT}{T_{t_2}}$$

These calculations are performed by the computer/display.

Table V gives inputs, function range, and slew rates for parameters for engine temperature ratio computation.

d. <u>Maximum Limit Parameters</u> - The computer/display mechanizes maximum limit parameters of

EGT overtemperature

Engine overspeed

Low oil pressure (for N > 90 percent)

High oil temperature

Limits for the parameters and conditions under which the tests are valid are shown in Table III.

<u>High Operating EGT</u> - The EGT operating overtemperature limit is set at the maximum limit with hot section inspection mandatory should the limit be exceeded. To preclude loading of the EGT thermocouple system, the limit switch is located directly on the servo shaft of the modified MIL-I-27209-A servoed EGT cockpit indicator. Closure of the switch will provide voltage to the failure flag in the computer/display, dropping and latching the over-limit flag. Provisions are made to internally adjust the trip level by ±111°C. The adjustment is inside the EGT indicator case. Dynamic response of the system is limited by the thermocouples.

An interlock with a 50 percent spool speed switch on the N servo deactivates the detection circuit whenever the engine is below 50 percent rpm, which will be during start and shut-down. The limit is 704.4°C (see the hot start discussion).

<u>Engine Overspeed</u> - Two limits are monitored and displayed to test the engine for overspeed. The lower limit (High N) requires compressor and turbine inspection. The higher limit (Max N) requires removal and teardown of the engine. The limit switches are on the N servo repeater shaft in the computer/display.

The two limits, which were obtained from the F-105D Flight Manual, T.O 1F-105D-1, dated 15 July 1952, are 106.5 percent N_2 and 108 percent N_2.

TABLE V

J75-P-19W/F-105D ENGINE TEMPERATURE RATIO COMPUTER/DISPLAY INPUTS, FUNCTION RANGES AND SLEW RATES

Input	Function	Source	Range	Slew Rate	Scale Factor
P_{t_2}	---	See Table IV	See Table IV		See Table IV
EGT	---	EGT Indicator Modified MIL-I-27209-A	700°R (116°C) to 2350°R (1032°C)		
N_2	---	Aircraft Tachometer per MIL-G-26611 Type GEU-7A	0 to 120 percent N_2	NA	
--	T_{t_2}	Computer/Display Isolation Transformer	390°R (-57°C) to 1100°R (338°C)	3°F (1.7°C) per sec	
--	N_2	Computer/Display Servo Repeater	0 to 120 percent N_2	25,000 rpm/min	
--	N_2'	Computer/Display N_2' Servo Repeater	6000 to 9500 rpm	Compatible to N_2 and T_{t_2} Rates	
--	RNI	Computer/Display RNI Servo	0 to 0.6	Compatible to P_{t_2} and T_{t_2} Rates	

<u>Low Oil Pressure</u> - Sub-normal oil pressure at cruise or higher power levels can be a serious problem in a jet engine since the oil functions as a coolant as well as a lubricant. The Computer/Display monitors the output of a pressure switch in the oil line (a pressure transducer is used for the Signal Data Translator input).

The existing low oil pressure warning switch is utilized to trip the Computer/Display warning flag. Diode isolation precludes undesirable loading effects on the pilot's indication. Characteristics of the switch are:

Opens for $P_{oil} > 39$ psid

Closes for $P_{oil} < 23$ psid

The low-limit flag is interlocked with a 90-percent N_2 switch to preclude nuisance trips due to low oil pressure under starting and shutdown conditions.

The appropriate limits were obtained from the F-105D Flight Manual mentioned previously.

<u>High Oil Temperature</u> - Due to the importance of the oil's bearing coolant function, high oil temperature is a cause for concern. Scavenge oil temperature is monitored as a limit function, with the limit set at 710°R (121°C), which was obtained from the F-105D Overhaul Instructions, T.O. 2J-75-3, dated 1 Nov 1961.

<u>High Oil Consumption</u> - Provisions for mechanizing at a later date a flag indication whenever the oil consumption exceeds a predetermined limit are incorporated in the Computer/Display.

e. <u>Expended Hot Section Factors</u> - Theoretical data exist relating "hot section growth factors" to the exhaust gas temperature. The theory is that operating at elevated temperatures accelerates the aging or deterioration of the engine's hot section. This rate of expenditure increases with temperature slowly at first but becomes very severe as temperature increases. The validity of this theory and the correlation of expended life values to engine condition are currently being evaluated by the Air Force. Because of the theory behind the concept and the keen current interest in the technique, the Computer/Display incorporated circuitry to monitor exhaust gas temperature with a non-linear drive and timer. The engine's accumulated expended life factors are displayed on the face of the Computer/Display. The display can be reset with the appropriate engine expended life in the event of replacing the engine or Computer/Display.

f. Engine Operating Time - Engine Operating Time is monitored by actuating a counter whenever spool speed exceeds 50 percent N_2. The power sequencing is accomplished through a relay drive from the 50-percent switch on the N_2 servo.

g. Computer/Display Elapsed Time - The Computer/Display elapsed time will be accumulated by a counter driven directly from the input power line to the unit. Whenever power comes on, time will be accrued.

2.2.2.2 Computer/Display Modules

The Computer/Display is physically composed of four modules and the chassis. Figure 7 shows the electrical and physical layout of these modules. The four modules are identified as the Servo Module, labeled S in the diagrams, the Self-Test Module, labeled T, the Network Module, W, and the Spool Speed Module, N. The chassis mounted parts are identified as C. The block diagram in Figure 7 indicates the electrical layout of the unit and the extent of each of the modules and the wiring mounted to the chassis. The exploded view shows the physical arrangement of the modules. The front and back panels and the supporting base compose the Computer/Display chassis and are inseparable in field maintenance. The four modules are easily removed for checkout and for replacement.

2.2.2.3 Computer/Display Self-Test

Self-test for the Computer/Display is actuated by the switch in the upper left corner of the Computer/Display face, shown in Figure 7 . The first position of the switch, marked NO TRIP, simulates a normal engine operating condition in the Computer/Display; none of the flags should drop during this phase of self-test. Position two of the self-test. Position two of the self-test switch, marked TRIP, simulates an abnormal operating condition in the Computer/Display, during which all the flags must drop.

A schematic wiring diagram of the self-test circuitry is shown in Figure 8. When the self-test switch is turned to position one, NO TRIP, a set of input signals corresponding to a typical engine operating condition is applied to the Computer/Display by resistive dividing networks and a synchro (for fuel flow). As mentioned above, none of the Computer/Display flags should drop. Position two of the self-test switch, TRIP, applies a set of signals corresponding to an abnormal operating condition. This is simulated by an improper spool speed signal for the other operating conditions. This abnormal condition will trip both the high consumption flag and the high engine temperature ratio flags. The remainder of the flags, which are switch operated, are tripped by the position "2" self-test circuitry. All the flags should, therefore, trip when the self-test switch is in position "2."

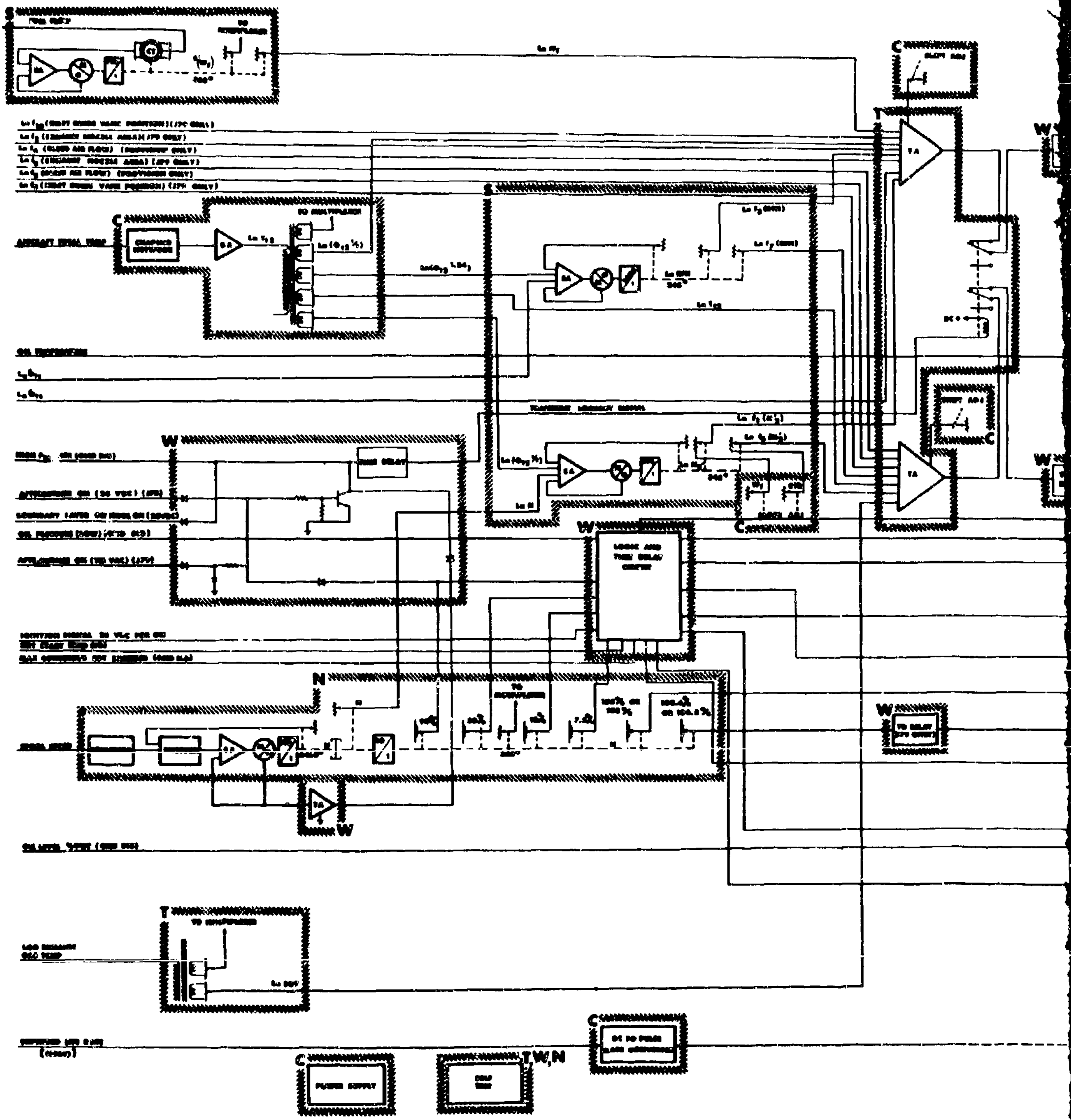

Figure 7. Block Diagram and
Computer/Display

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Los Angeles California

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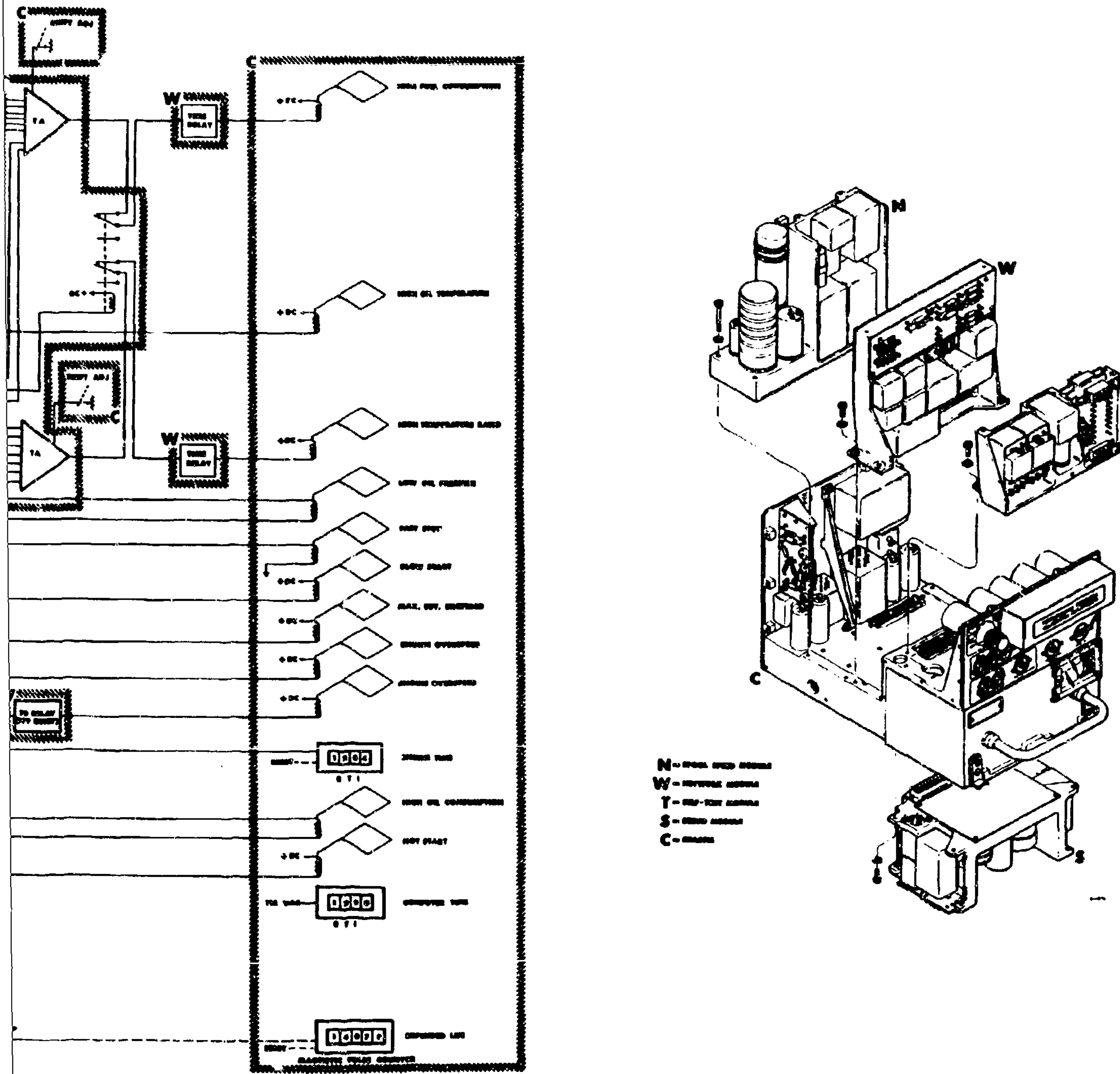

lock Diagram and Exploded View of
omputer/Display

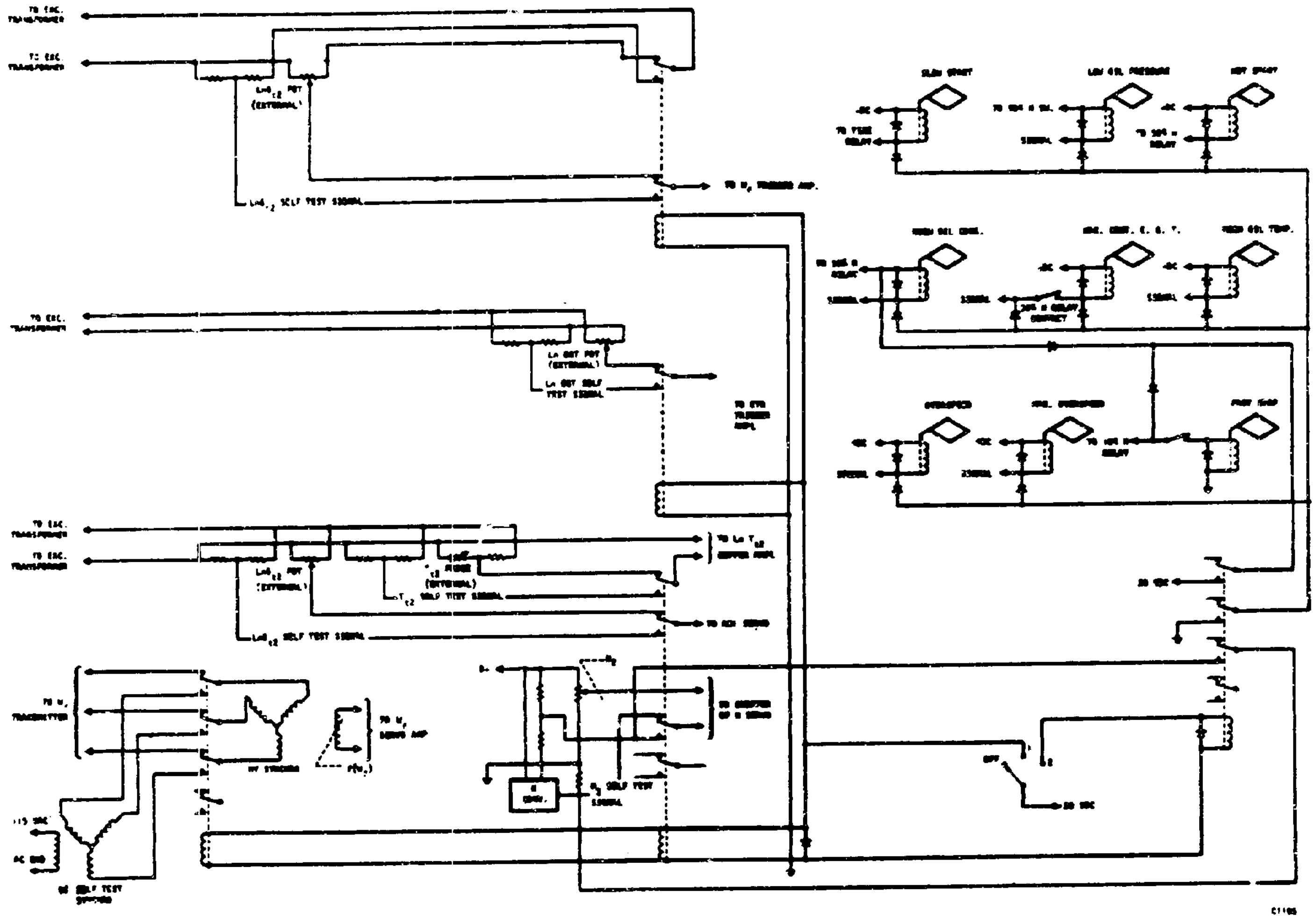

Figure 8. Computer/Display Self-Test Circuitry

2.2.2.4 Computer/Display Calibration Adjustments

The controls for the calibration adjustments which adapt the Computer/Display for engine-to-engine variations and for transducer variations are shown in Figure 9.

2.2.3 Signal Data Translator

The Signal Data Translator is a second major component of the Engine Analyzer System. This unit is shown in Figure 10. A front view photograph of the Signal Data Translator is shown in Figure 10a.

The purpose of the Signal Data Translator is to present to the Recorder a number of digital and analog signals. The digital signals from the thumbwheels can be seen in Figure 10. This documentary data is composed of the aircraft and engine serial numbers, flight number, and date; the twenty thumbwheels can be seen in the figure. The switch inputs, e.g., afterburner on and water injection on, are also essentially digital, since the function conditions are represented by a voltage or lack of voltage. The analog signals are those from the engine transducers.

Table VI lists the inputs to the Signal Data Translator, and their sampling frequency, while Table VII lists the source of each. The analog signals from various transducers are conditioned to a zero to five volt dc standard-voltage analog format, and then converted to binary coded decimal digital format. The numbers derived from the BCD conversion then time-share an output circuit with the outputs from the thumbwheels and on-off air frame switches. Each resultant number has 12 bits. The numbers are presented to the recorder as three serial digits in BCD NRZ format. A parity bit is computed by the Signal Data Translator and presented with each BCD digit.

A complete record of all inputs occurs in the first 20 seconds of each minute. Every 60 sec is a frame and every 1/48 of a second is a channel.

A complete breakdown of the frame, channel, and record is shown in Figure 11.

A complete record occurs in the first 20 seconds because the hundreds digit of channel 01 receives 20 different inputs from the 20 SDT thumbwheel switches. One of the 20 SDT thumbwheel switch inputs is sequenced into channel 01 during each record. All of the other 47 data channels are completely sampled over during each second. The other aircraft switch functions are recorded on the tens and units digit of each 01 channel.

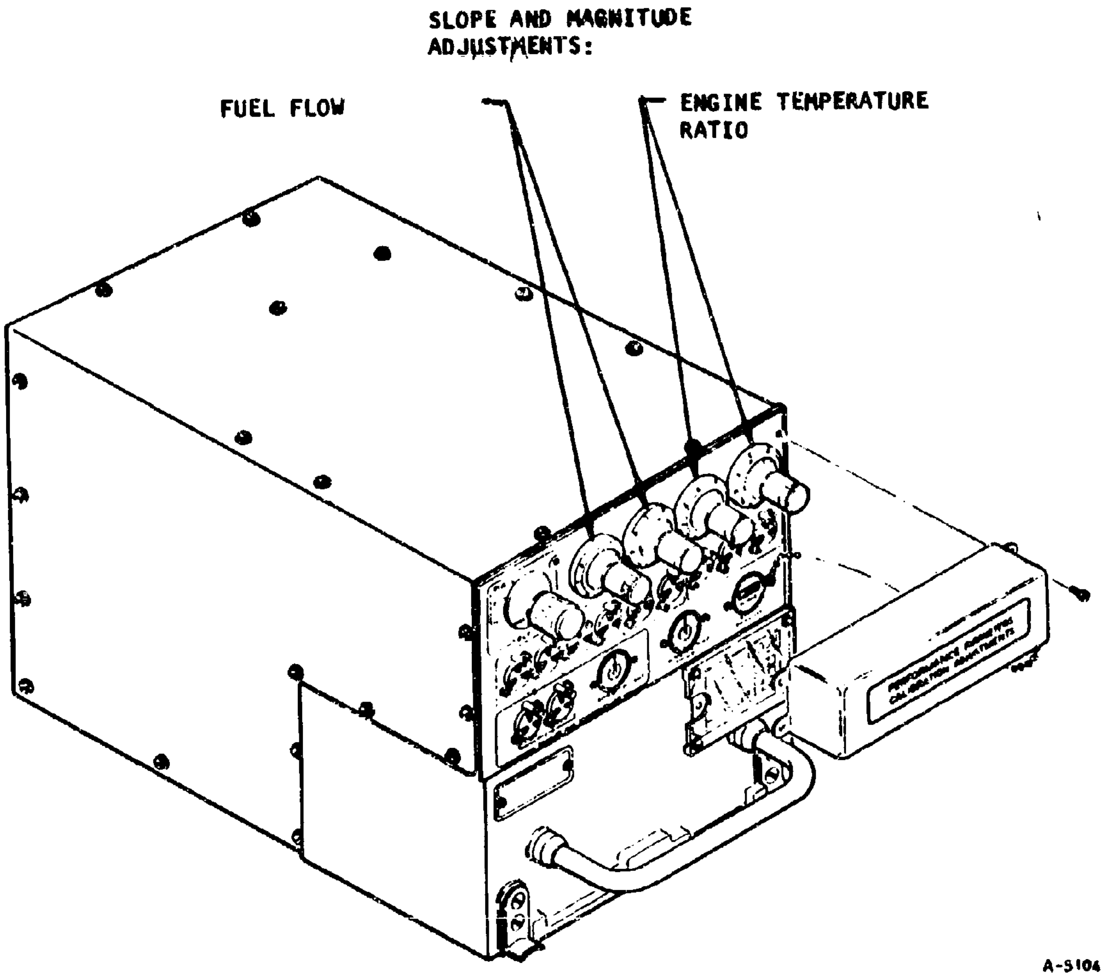

Figure 9. Computer/Display, Showing Calibration Adjustments

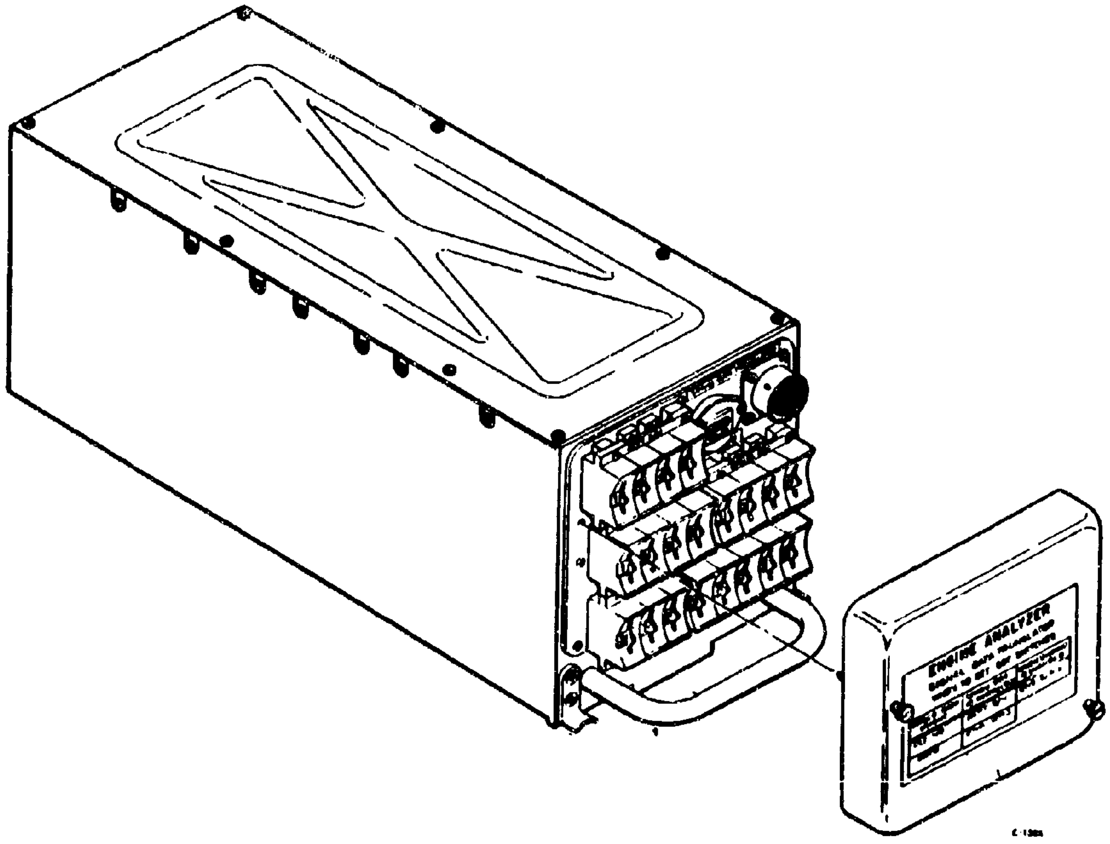

Figure 10. Signal Data Translator

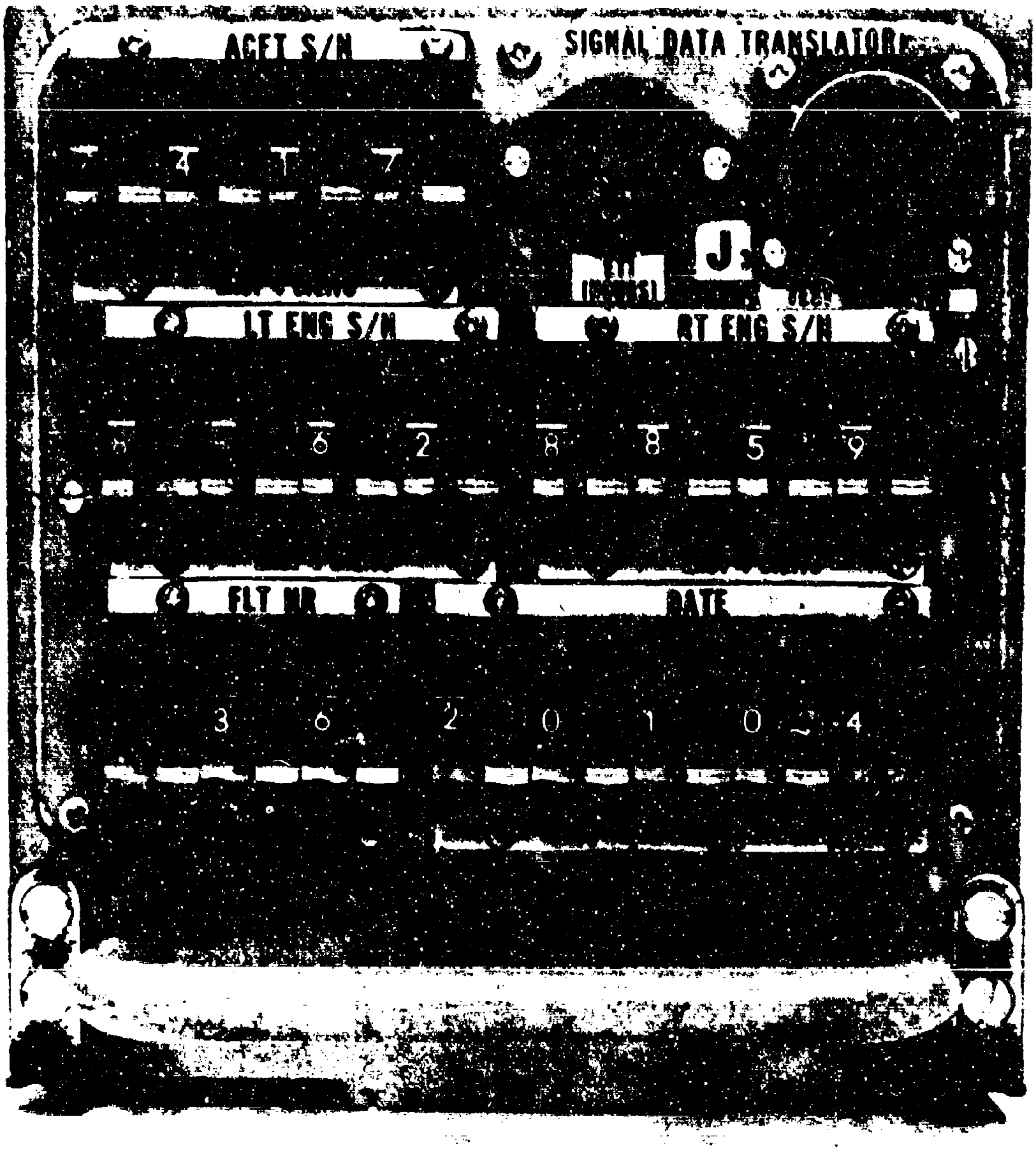

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Figure 10a. Front View Photograph of Signal Data Translator

TABLE VI

PARAMETER FREQUENCY OF SIGNAL DATA TRANSLATOR OUTPUT
F-105D ENGINE ANALYZER SYSTEM

Once Per Sec	Every 2 Sec	First 20 Sec of Each Min
W_f	P_{oil}	20 digits of documentary data, one digit each second
EPR		
PLA		
T_{cd}		
T_{t_2}		
EGT		
T_{oil}		
N_1, N_2		
P_{t_2}		
$P_{oil\ b}$		
IGN		
AB		
WI		
Anti-ice		

TABLE VII

SIGNAL DATA TRANSLATOR INPUTS

NOTE: All parameters are analog signals except switch functions

PARAMETER	CHANNEL Pri-mary	CHANNEL Cross Strap	SOURCE	DEVICE	RANGE	PARAMETER	CHANNEL Pri-mary	CHANNEL Cross Strap	SOURCE	DEVICE	RANGE
Inlet Conditions						**Lubrication System**					
1. Inlet Total Temp (T_{t2})	18	---	C/D	AC Transformer	390° to 1100°R	1. Oil Temperature	38	14	A/C	DC Resistance Probe	-65 to +350°F
2. Inlet Total Pressure (P_{t2})	27	45	A/C	DC Potentiometer	1.6 to 36 psia	2. Oil Pressure					
						a. TRU-20A	41	---	A/C	AC Variable Reluctance	0 to 100 psid
3. Water Injection On	---	---	A/C	Switch	---	b. MH-5	40(Sin) 46(Cos)	--- ---	A/C	AC Synchro	0 to 100 psid
Compressor Conditions						3. Oil Breather Pressure	29	23	A/C	AC Variable Reluctance	10 to 25 psia
1. Compressor Discharge Temperature	39	21	A/C	DC Resistance	600 to 1500°R	**Initial Condition**					
2. Compressor Discharge Pressure	17	35	A/C	AC Variable Reluctance	0 to 310 psi	1. Ignition On	---	---	A/C	Switch	---
						2. Afterburner On	---	---	A/C	Switch	---
3. Spool Speed, N_2	9	33	C/D	DC Potentiometer	0 to 120% N	**Documentary Data**					
						1. Aircraft Number	---	---	SDT	Thumbwheel Switches	---
4. Spool Speed, N_1	3	---	A/C	AC Tachometer	0 to 120% N	2. Engine Number	---	---	SDT	Thumbwheel Switches	---
5. Anti-Ice On	---	---	A/C	Switch	---	3. Flight Number	---	---	SDT	Thumbwheel Switches	---
Fuel System											
1. Power Lever Angle	2	20	A/C	DC Potentiometer	0-105°	4. Date	---	---	SDT	Thumbwheel	---
2. Fuel Flow	19	37	C/D	DC Potentiometer	0-28,000 pph						
Turbine											
1. Exhaust Gas Temperature	30	42	C/D	AC Transformer	700° to 2350°R						
2. Engine Pressure Ratio	16(Sin) 22(Cos)	--- ---	A/C	AC Synchro	1.2 to 3.4						

CODE: A/C --- Aircraft
C/D --- Computer/Display
SDT --- Signal Data Translator

A-3897

TABLE VIII

TIME SEQUENCE OF SIGNAL DATA TRANSLATOR OUTPUT

F 105D (J75 ENGINE)

THIS TABLE SHOWS WHAT SIGNALS ARE TO BE RECORDED IN EACH 1/48TH SECOND TIME SLOT DURING AN ENTIRE MINUTE. THE SIGNAL PATTERN IS IDENTICAL IN EACH SUCCESSIVE MINUTE.

TIME IN SECONDS (1–60) — NEXT CYCLE (1, 2, 3)

TIME WITHIN EACH SECOND MEASURED IN 1/48THS OF A SECOND

TAPE GAPPING LOGIC NO DATA TO BE RECORDED

Time slot	Signal
1	SIGNALS FROM 20 BED SWITCHES AND 8 ON-OFF SWITCHES. NUMBERS INDICATE WHICH BED SWITCH IS BEING SAMPLED. ALL ON-OFF SWITCHES ARE SAMPLED EACH SECOND.
2	POWER LEVER ANGLE
3	SPOOL SPEED (N1)
4	REFERENCE 0.25 V AC, 1% OF FULL SCALE
5	REFERENCE 472 MV AC, 94.4% OF FULL SCALE
6	REFERENCE 50 MV AC, 1% OF FULL SCALE
7	REFERENCE 4.750 V DC, 95% OF FULL SCALE
8	(NOT USED)
9	SPOOL SPEED (N2)
10	REFERENCE 12.5 V AC, 50% OF FULL SCALE
11	REFERENCE 5 MV AC, 1% OF FULL SCALE
12	REFERENCE 5 V AC, 100% OF FULL SCALE
13	REFERENCE 50 MV DC, 1% OF FULL SCALE
14	OIL TEMPERATURE
15	(NOT USED)
16	ENGINE PRESSURE RATIO (SIN)
17	COMPRESSOR DISCHARGE PRESSURE
18	INLET TOTAL TEMPERATURE
19	FUEL FLOW
20	POWER LEVER ANGLE
21	COMPRESSOR DISCHARGE TEMPERATURE
22	ENGINE PRESSURE RATIO (COS)
23	OIL BREATHER PRESSURE
24	REFERENCE 5 V AC, 100% OF FULL SCALE
25	(NOT USED)
26	TRANSIENT LOCKOUT SIGNAL
27	INLET TOTAL PRESSURE
28	(NOT USED)
29	OIL BREATHER PRESSURE
30	EXHAUST GAS TEMPERATURE
31	(NOT USED)
32	SPARE
33	SPOOL SPEED (N2)
34	(NOT USED)
35	COMPRESSOR DISCHARGE PRESSURE
36	REFERENCE 5 V AC, 100% OF FULL SCALE
37	FUEL FLOW
38	OIL TEMPERATURE
39	COMPRESSOR DISCHARGE TEMPERATURE
40	OIL PRESSURE (SIN) ♦
41	OIL PRESSURE
42	EXHAUST GAS TEMPERATURE
43	REFERENCE 4.250 V DC, 85% OF FULL SCALE
44	(NOT USED)
45	INLET TOTAL PRESSURE
46	OIL PRESSURE (COS) ♦
47	SPARE
48	REFERENCE 7.5 V AC, 50% OF FULL SCALE

HC HORIZONTAL CHECK CHARACTER (LONGITUDINAL PARITY) ONE CHARACTER TIME ONLY

♦ ALTERNATE SECONDS ONLY

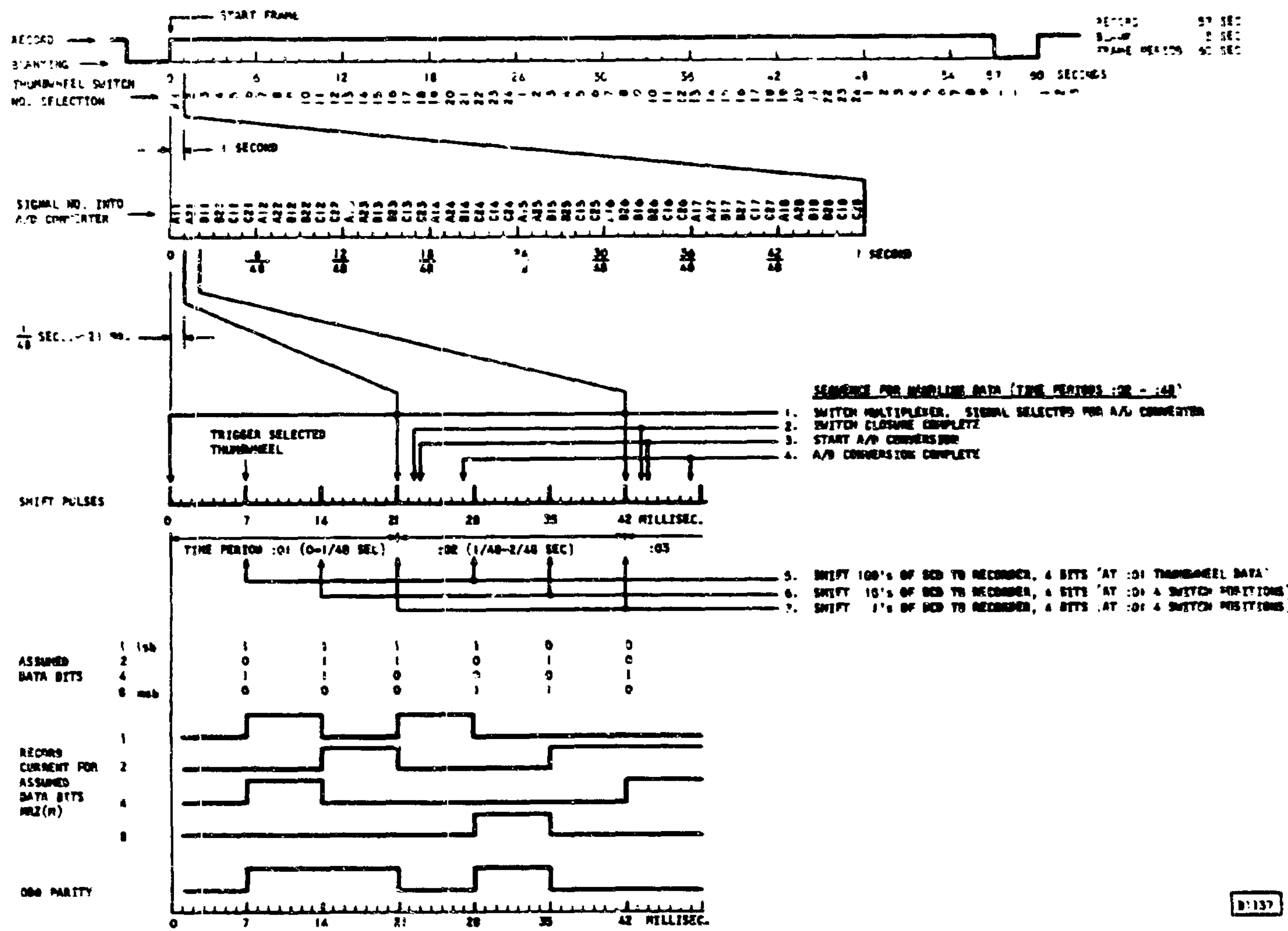


Figure 11. System Timing Diagram Recording System Signal Data Translator and Recorder

2.2.3.1 Signal Data Translator Theory of Operation

A schematic diagram of the Signal Data Translator is shown in Figure 12. As this drawing illustrates, the Signal Data Translator is functionally divided into the following areas: (1) calibration, signal preconditioning and a-c signal conditioning; (2) submultiplexers and multiplexer; (3) thumbwheel switches; (4) analog-to-digital converter; (5) signal gate; (6) parity generators; and (7) programmer and sequence generator.

The system uses several different types of transducers and sensors, e.g., synchros, variable reluctance devices, resistance elements, and potentiometers, to measure the various engine performance parameters. The signal data translator furnishes the required excitation to these transducers. The signal conditioning transforms the signals from these various transducers to d-c voltages in a 0 to +5v range. These signals are sequenced by the multiplexers, and converted to digital format.

The thumbwheels, which have digital outputs, are also presented sequentially. The signal gate time-shares the output with the converted analog signals, the thumbwheel signals, and the inputs from the engine and airframe switches (i.e., ignition, anti-ice, afterburner, and water injection). The parity and NRZ generator determines the parity of the output and presents the output and its parity bit in NRZ format to the recorder.

a. Calibration and Signal Preconditioners - Both a-c and d-c analog transducer signals and calibration voltages are supplied by the transducers. All signals must be converted to standard 0-5 v dc for subsequent conversion to digital format. The d-c signals and calibration voltages are preconditioned to 0-5 v dc by simple resistive dividers.

The a-c signals are grouped into three sets. Each set is preconditioned to the same a-c voltage range. Each signal of a given set is converted to 0-5 v dc by an a-c conditioner. The a-c signal preconditioner makes use of transformers to change voltage levels.

The preconditioning circuits also provide standard calibration signals which perform two functions: first, they verify the accuracy (scale factor or gain, and null) of the ADC and of each a-c to d-c signal conditioner; second, in the case of the a-c conditioners, they enable ground-based data reduction to correct for transducer scale factor errors caused by variations in the 115-v, 400-cps line supply.

Several different types of transducers and sensors supply data to the Signal Data Translator. Some of these must be excited by the SDT in order to provide semistandardized signals which can be handled by the time-shared signal conditioners. The following paragraphs describe this excitation and the preconditioning required to provide signals which may be either directly connected to the analog-to-digital converter or connected to one of the three a-c to d-c signal conditioners.

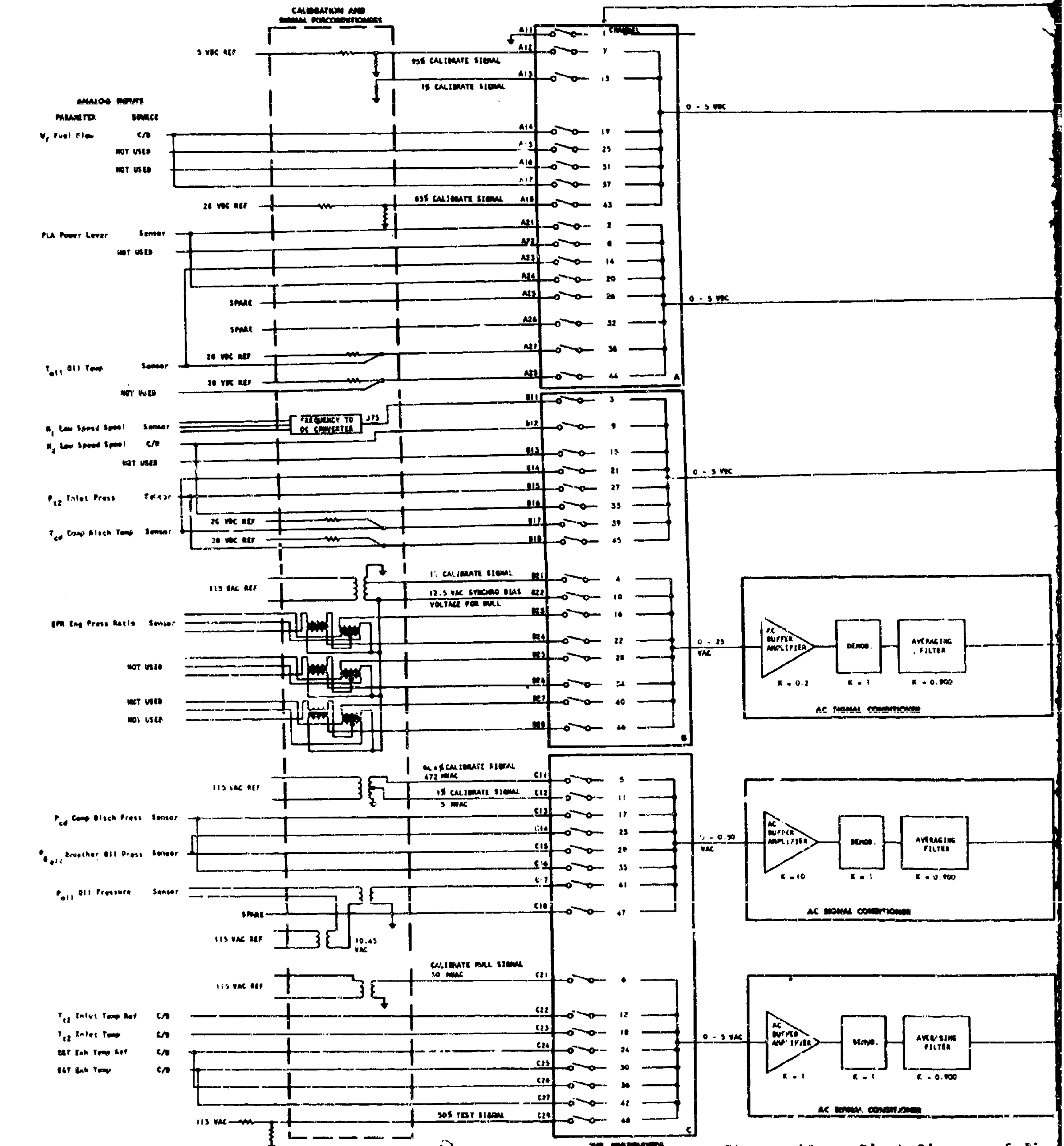
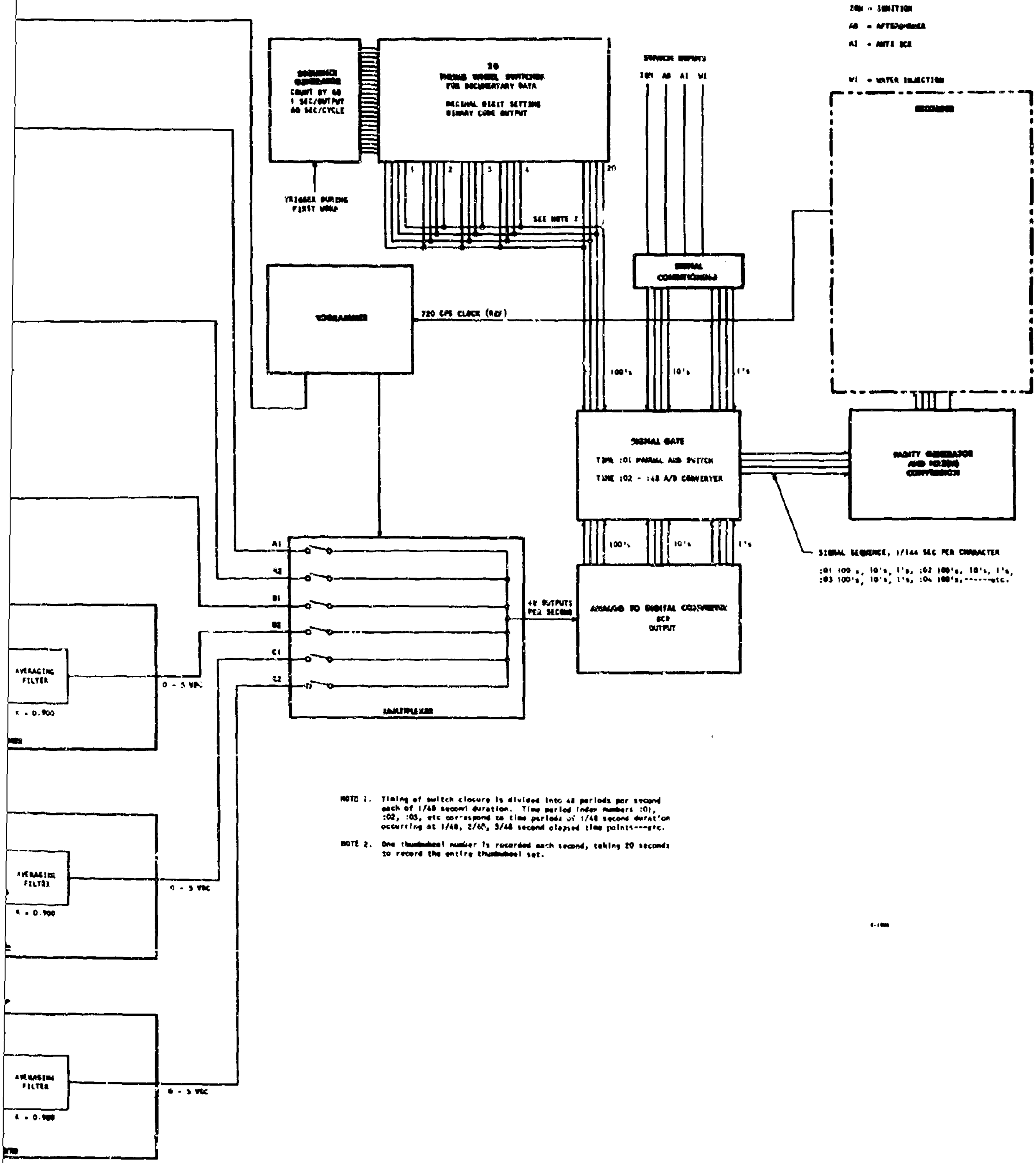


Figure 12. Block Diagram of Sig



NOTE 1. Timing of switch closure is divided into 48 periods per second each of 1/48 second duration. Time period index numbers :01, :02, :03, etc correspond to time periods of 1/48 second duration occurring at 1/48, 2/48, 3/48 second elapsed time points---etc.

NOTE 2. One thumbwheel number is recorded each second, taking 20 seconds to record the entire thumbwheel set.

Diagram of Signal Data Translator

B

Synchros - The synchro signal inputs are three wire delta signals, the three voltages being spaced 120 deg apart (space phase). The three-wire, 120-deg signal is converted to a four-wire, 90-deg, resolver-type signal and recorded as two perpendicular components of the synchro angle vector. The conversion is accomplished with two Scott T-connected precision transformers which yield the sine and cosine of the input angle.

In addition to the transformer T, a bucking voltage transformer is used for synchro signal preconditioning. Since the a-c to d-c signal conditioners require a single-phase voltage input, the converted synchro voltages are offset by 12.5 v, converting the nominal voltage range, 11.8 v in-phase to 11.8 out-of-phase, to a new range of 0.7 to 24.3 v in-phase. By recording a wider range, 0 to 25 v, as 0 to 1000 counts, assurance is provided that individual transformation ratio variations from one synchro to the next will not result in off-scale voltage signals. The offset voltage is also recorded to provide an exact null point definition and allow precise calculation of synchro angles, independent of expected variations in excitation voltage or synchro transformation ratio

Variable Reluctance, 10.45 to 15.55 v - This signal results from the unbalance of a 26-v bridge circuit in the transducer which is balanced at mid-scale. Since the signal conditioning circuits are designed to operate on a zero to maximum voltage signal, a bias voltage is subtracted from the incoming signal. The bias voltage shifts the range of the input to 0 to 5.1 v. An additional precision stepdown transformer provides signal isolation and changes the voltage range to 0 to 500 mv, in order to be able to use the same signal conditioner as the other variable reluctance transducers.

Variable Reluctance, 0 to 500 mv - This signal is obtained from several AiResearch-supplied transducers. These are bridge unbalance devices, as is the type described above; however, they are electrically connected internally to provide an output which varies from 0 to 500 mv for the full range of input values. The transducer scale factor is defined as 50 mv/v for full scale; the signal data translator provides an excitation voltage of 10 v which gives the 500 mv full-scale range.

Resistance Probe Temperature Sensors - Two types of resistance probes are used for temperature sensing; one has a nominal resistance, of 50 ohms, the other, nominally 90 ohms at 0°C. A d-c current of approximately 10 ma, in the case of the 50-ohm probes, or 5 ma in the case of the 90-ohm probes, provides an output within the five volts dc input range at the maximum temperature of the required ranges. Series precision resistors from the 28-v d-c supply to the probes, selected to deliver the desired currents into the known maximum probe resistances, provide simple and effective means of converting the probes' temperature-resistance functions into usable voltage signals. Due to the finite source impedance feeding each probe, the current through the probe will be partly a function of probe resistance, i.e., the voltage across the probe will not be strictly proportional to probe resistance. The relationship is, however, defined so that the ground computer can be supplied with the exact temperature-voltage function for each probe network.

To make these temperature probe measurements independent of variations in the 28-v dc supply voltage, a reference signal given by a fixed precision divider from the 28-v d-c supply is also recorded.

400-cps Signals from Computer/Display - Two quantities, EGT and T_{t_2}, are supplied from the Computer/Display in the form of 400-cps signal outputs from buffer amplifiers through transformers. These signals are handled in much the same way as the 500-mv transducer signals. The primary difference is that these signal circuits' excitation voltages, which determine the signal scale factors, are supplied by the Computer/Display unit, rather than by the Signal Data Translator. To avoid possible scale factor errors, an excitation reference signal is recorded with each information signal. The exact excitation used in the Computer/Display is, therefore, known; moreover, the signal can be corrected for variations in this excitation during ground computer data reduction.

Potentiometers - All potentiometers, whether located in the Computer/Display or externally mounted in the aircraft, are handled electrically in the same way. Excitation for the potentiometers is provided from the same supply as the ADC reference voltage. The resistance ratio output of the potentiometer is thus converted to a voltage input to the ADC with the same scaling as the ADC reference.

Tachometer Signal - Since the low-pressure spool speed is not used in the Computer/Display, this signal must be conditioned in the Signal Data Translator. However, it is a signal of precisely the same form as the tachometer input to the Computer/Display; the same frequency to d-c voltage conditioner is used in the Signal Data Translator as in the Computer/Display, providing a d-c voltage to the ADC.

Calibration References - In addition to the true information channels, nine words in each 1-sec subframe are used to record calibration signals, as a continuing check on the accuracy of the SDT. Two kinds of such signals are used, d-c and a-c.

Two d-c signals are obtained directly from resistive division of the basic ADC 5-v reference supply. One is a signal voltage of 1 percent of the reference, in order to check possible ADC null drift; the other is a 95-percent signal, checking ADC scale factor. Between these two signals, the accuracy of the ADC is verified. A third d-c signal of 85 percent of full scale is derived from the 28-v supply, since this supply is used to deliver excitation current to the temperature probes, and the probe excitation current is proportional to this voltage. This calibration signal is to be used as a scale factor correction on all temperature probe voltages.

Two a-c voltage levels also are provided at the input to each a-c to d-c signal conditioner during each 1-sec subframe. These are 94.4 percent and 1 percent of full scale. The 1-percent signal verifies the null accuracy of the signal conditioner; the 94.4-percent signal verifies gain, or scale factor. Also, since the a-c signals are obtained from voltage ratio devices which are excited from the aircraft line voltage, and since this line voltage will fluctuate with time, this calibration check is required to correct for line voltage variations as well as possible signal conditioner gain errors.

b. Signal Conditioners - The input signals and preconditioning circuits simplify the signal conditioning problem. The submultiplexer outputs are all in the form of either a d-c signal, which can be directly connected to the ADC, or an a-c voltage signal with a range from zero to some maximum voltage, with the same maximum voltage for every signal which connects through a given submultiplexer. Each signal conditioner is, therefore, only required to convert a range of a-c voltage to a standard range, 0 to 5 v, of dc. This is accomplished by operating on the signal successively with a stable fixed-gain a-c amplifier, a precision demodulator, and a smoothing filter.

Amplifiers - The basic amplifier circuit is a three-stage, direct-coupled amplifier, utilizing heavy overall feedback both for a-c gain stability and d-c bias stabilization. The gain stability is approximately 0.2 percent over a wide range of temperatures up to the maximum temperature required.

Demodulators - The demodulator circuit switches on and off synchronously with the 400 cps line power. The circuit has very little low temperature drift and contributes an error of 0.05 percent.

Filter - The four-element Bessel filter designed for these signal conditioners has a total ripple and settling time error below 0.1 percent. The filter has four reactive elements and a nominal corner frequency of approximately 40 cps.

c. Multiplexers - All of the analog transducer signals are scanned by six submultiplexers in a fixed time sequence. Signals with the same characteristics are scanned by the same submultiplexer.

The outputs from the signal conditioners, as well as the signals that were already in the 0 to 5 v dc format, go to the multiplexer. The multiplexer samples each of the six submultiplexer output signals in turn in a fixed time sequence. The multiplexed signal then goes to the analog-to-digital converter.

The switching elements of the multiplexers are reed relays which are controlled by the SDT programmer. The relays are described in the following paragraphs.

Relay Driver - To isolate the logic and counting circuits in the programmer from the voltage pulses associated with switching the relays, which are inductive loads, separate transistors are used as relay drivers. This method ensures that the inductive voltage spikes likely to result from switching the relay coils will not cause spurious counts or erratic switching; also, it allows the logic circuits to run at relatively low power levels.

The relay driver circuit accepts a logical zero (ground) input from the programming logic and provides a ground signal to one end of the relay coil load; the other end of the relay coil is permanently connected to the positive voltage supply. Two transistors are used to provide the required current multiplication. Both are operated as grounded emitter inverter stages. The first is normally biased off and is switched on by the NAND gate ground signal to command the relay to turn on. The second transistor then turns on, allowing current to flow through the relay coil. Although the NAND gate itself is designed to drive only a 1.5-ma load, the current multiplication in the 2-transistor driver circuit readily provides the approximately 60 ma required by the 2-pole relays in the submultiplexers.

Zener diode protection is used to limit the voltage spike produced when the coil is switched off and to protect the coil driver transistor from overvoltage. This method is preferred to a simple shunt diode because of the faster relay dropout time it provides.

Switching Element - A reed relay consists of one or more reed switch elements and a d-c actuating coil. The relay contacts are hermetically sealed in a glass capsule containing an inert gas. The switch elements, or reeds, are made of a nickel-iron alloy. The contact surfaces are gold-plated for this application to provide reliable life and performance for switching the low-level signals of the engine analyzer transducer. The coil is provided with a magnetic shield which improves the magnetic circuit and isolates adjacent switch assemblies from stray magnetic field interactions that might otherwise affect pull-in or drop-out characteristics.

d. Thumbwheel Switches - The thumbwheel switches are rotating devices which display each digit on a counter drum dial. The drum for each digit may be rotated individually to the desired number. A connector at the back of each counter wheel provides five wires which give an electrical BCD representation of the digit which is set to show on the face of the switch. The wires are for the 8, 4, 2, and 1 binary bits, representing the digit displayed, and an excitation or common lead. Wiper contacts, mounted on the display drum, travel over a printed circuit card with the rotation of the drum, and successively connect the common lead to the various output bit leads required to define each decimal digit in turn. The logic language is a closed circuit for a one bit and on open for a zero bit. As described in the programming and sequencing discussion, the common leads of the 20 thumbwheel switches are successively energized to provide commutation between the switches in the recording sequence.

e. Analog-to-Digital Converter - The analog-to-digital converter changes each of the 0-5 v dc signals in the sequence from the multiplexer into numbers of three four-bit digits (binary-coded decimal), which is the format required by the system recorder.

The analog-to-digital converter is of the voltage ramp type. These devices digitize input voltages by generating a time period as a function of the input voltage and gating a counter during this time period.

The components of the system are: (Figure 13)

1. A voltage ramp generator to provide a signal with constant rate of change of voltage.

2. A switching network and steering logic to condition the ramp generator signal and input voltage for the zero crossing detector

3. A zero crossing detector to provide an indication of the zero voltage and the input (measured) voltage ramp crossover points

4. A reference power supply for excitation of the input devices and to provide a reference voltage for the ramp generator

5. A gatable BCD Counter for conversion of the time period to a BCD output

At the receipt of a signal at the reset input, the ramp generator, switching networks, and counter are all set to their initial state. After the removal of this signal, a negative-going voltage ramp is initiated by the ramp generator. The switching logic adds the input from the ramp generator to a small bias voltage to generate a voltage which starts slightly positive and progresses toward zero. This voltage is then applied to the zero-crossing detector. As this voltage crosses zero, the detector provides an output to the steering logic, changing the state of its memory element, and starts the counter. The switching network then adds the previously generated ramp voltage, which is now zero and progressing in a negative direction, to the input signal and resets the zero-crossing detector The input to the detector will now be positive by an amount proportional to the input signal. As the voltage ramp progresses in a negative direction, the detector input will again cross zero, providing an output which is used to stop the counter. The time the counter was operating is, therefore, directly proportional to the input voltage, and the accumulated count is a digital representation of the input.

f. Signal Gate - The inputs to the signal gate come from the aircraft switches and the thumbwheel switches, and from the output of the analog-to-digital converter. According to timing signals received from the programmer, the signal gate selects the output word from either the ADC or the switches, and either the hundreds, tens, or units digit of the chosen word, and presents this digit to the NRZ(M) converter.

Parity Generator and NRZ(M) Converter - The parity generator and NRZ(M) "non return to zero" converter receive their inputs from the signal gate. The signal gate output is the four bits associated with one decimal digit.

The parity generator uses the signal gate outputs to compute even parity. If either one or three of the four inputs to the parity generator is ONE the output of the parity generator will be a ONE. If either none or two of the four inputs to the parity generator is ONE, the output of the parity generator will be ZERO.

The NRZ(M) converter has a five bit register. The five inputs to this register are the four bits selected by the signal gate output and the output of the parity generator. If the input bit going to a specific flip-flop in the register is a ONE, the flip-flop will change state. If the input but going to a specific flip-flop in the register is a ZERO, the flip-flop will remain in its original state, resulting in the NRZ(M) format required by the recorder.

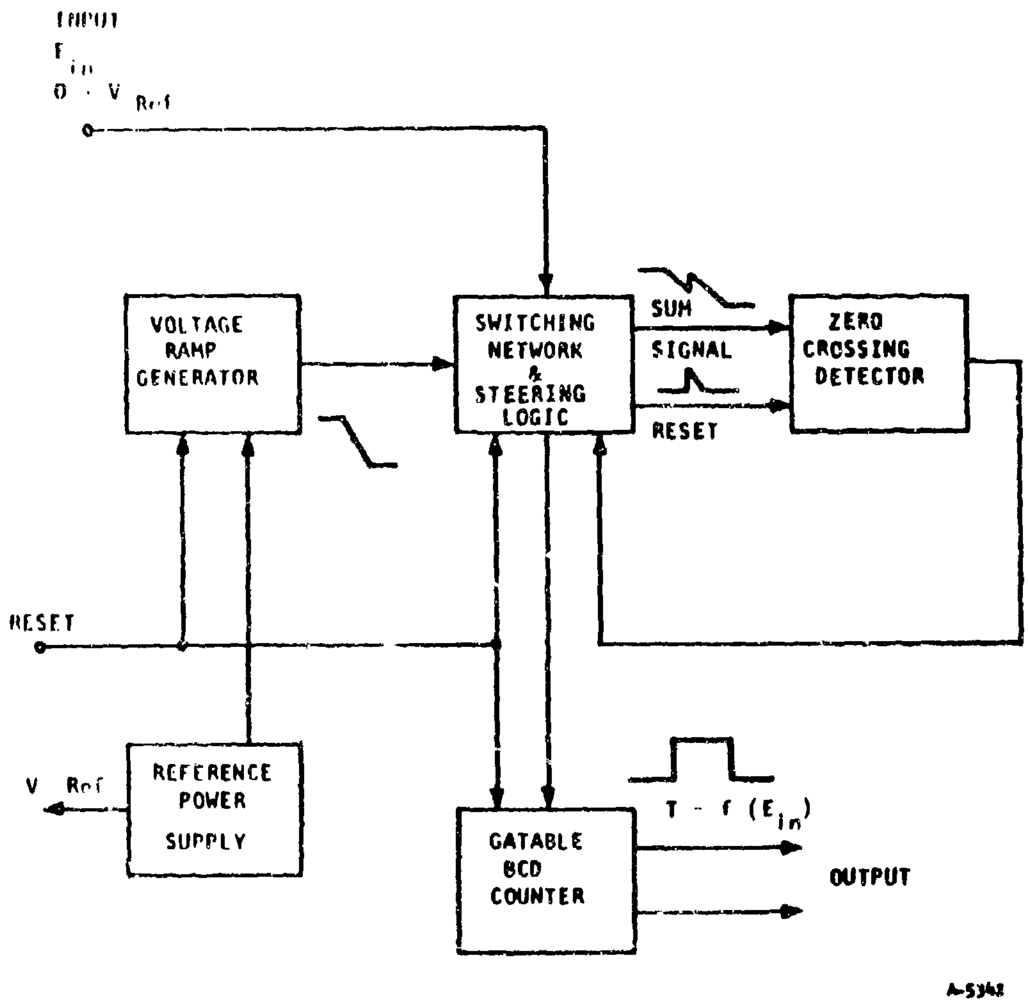


Figure 13. Analog-to-Digital Converter

g. Programmer - The programmer in the Signal Data Translator controls all the required time sequencing. It controls the opening and closing of the multiplexer and submultiplexer switches, as well as pulsing the analog-to-digital converter, and the signal gate.

System Timing - The programmer generates its timing pulses from the 720-cps clock frequency output of the Recorder; the data sequence presented to the Recorder is spaced directly proportional to the speed of the tape, resulting in a constant data density on the tape.

The basic recorded frame on the magnetic tape is 60 seconds. There are 57 seconds of continuous BCD recording, followed by 3 seconds of blanking. All incoming data are multiplexed so that each is recorded once per second with the exceptions noted in Table VI: oil pressure, P_{oil}, is only recorded once every 2 seconds, and the thumbwheel data are recorded one digit each second for the first 20 second of each frame.

During each 1-second subframe, 48 unique inputs are selected by the multiplexer and submultiplexer and presented to the ADC. A signal time period in the subframe is 1/48th second or approximately 21 millisecond. A time period is symbolized in the following discussion with a colon; for example, :17 refers to the period from 16/48 to 17/48 second after the start of a 1-second subframe.

Some of the programmer timing signals are used to close one of six multiplexer switches and simultaneously closes one of the eight six-pole switches on each of the submultiplexers. The switching sequence makes it possible to select 48 unique data channels in sequence. This is done in 48 time periods (Table VIII).

During time period :01 only, data for recording comes from the thumbwheel and aircraft switch inputs. During this time, the signal gate selects digital data from the switches. During time periods :02 through :48, the signal gate passes the data channeled through the submultiplexer and multiplexer and digitized by the analog-to-digital converter.

The following sequence of events occur during each time period from :02 through :48.

Start	0	1's BCD triggered from ADC register
	10 µs	Signal to switch multiplexer selection to next channel
	1.5 ms	Multiplexer switching completed, including contact bounce and transients
	2.5 ±.5 ms	ADC conversion starts
	6.1 ms	ADC conversion cycle complete
	6.94 ms	100's BCD triggered from ADC register

	15.88 ms	10's Binary-Coded Decimal triggered from ADC register
End	20.82 ms	1's Binary-Coded Decimal triggered from ADC register

Every 1/144 second, a four-bit digit enters the parity generator and NRZ(M) conversion unit. The four data bits enter the output registers and simultaneously set a parity register. Two microseconds after the incoming data arrives, an output command-pulse transfers the new bits to the recorder amplifiers. The data presented in Figure 11 show the time sequence of the Signal Data Translator output.

2.2.3.2 Signal Data Translator Modules

The Signal Data Translator is assembled in six functional modules: (1) the programmer, (2) the analog-to-digital converter, (3) the relay module, (4) the signal conditioner module, (5) the frequency-to-dc converter, and (6) the power supply. An exploded view of the Signal Data Translator showing these modules is presented as Figure 14. These modules are designed for easy removal.

2.2.3.3 Signal Data Translator Self-Test

The circuitry for the Signal Data Translator self-test is housed in a box separate from the SDT chassis. The self-test unit is connected to the Signal Data Translator through the connector on the SDT front panel, shown in Figure 14.

The Signal Data Translator self-test checks the signal conditioner, multiplexers, and the analog-to-digital converter.

To self-test the Signal Data Translator, the following operations must be performed.

a. Set the switch on the self-test unit to Position 1.

b. Depress the self-test unit pushbutton. The lamp on the self-test unit should light within 1 minute.

c. Repeat for switch Positions 2, 3, and 4. In each position, the lamp should light within 1 minute after the pushbutton is depressed.

If the lamp does not light under each of these conditions, the Signal Data Translator is malfunctioning.

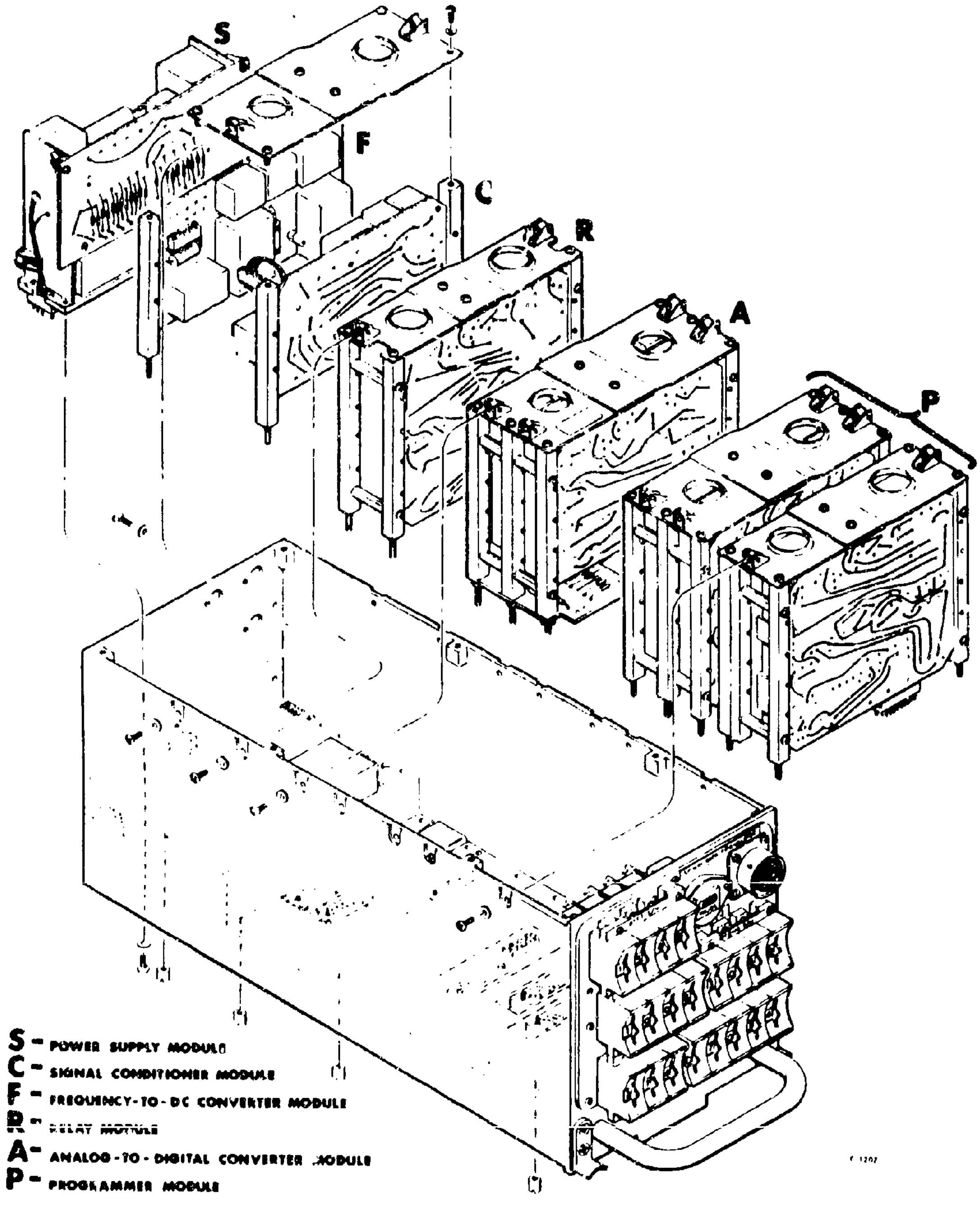


Figure 14. Signal Data Translator Exploded View

A schematic wiring diagram of the SDT self-test circuitry is shown in Figure 15. The circuit performs in the following manner: several reference voltages are applied to the Signal Data Translator. Since the amplitudes of these voltages are known, the outputs of the analog-to-digital converter can be computed. For each of the reference voltages used for self-test, the most significant decimal digit of the analog-to-digital converter output is examined. This is done as the self-test channel is being scanned. The three a-c signal conditioners and one of the d-c channels are checked.

A three-pole, four-position switch is used to select one of the four self-test channels. The signals that operate four of the multiplexer relays are used to determine when each of the four self-test signals have been selected. The 2's bit and 1's bit of the ADC output are the same for all four tests. Therefore, the two bits associated with the most significant decimal digit of the analog-to-digital converter output, the 8's bit and the 4's bit, are connected to the output line either directly or through an inverter. The circuitry is such that the output line will always be high whenever the analog-to-digital converter is correct. If the pushbutton switch is depressed when the output line is high, the SCR will be turned on, thus lighting the lamp.

2.2.4 Recorder

The third major component of the Engine Analyzer System is the Recorder. The Recorder, shown in Figure 16, produces a magnetic tape record in standard IBM format of the measured engine operation parameters, and the variation of each during the mission. These parameters are received by the recorder from the Signal Data Translator as digital NRZ(M) signals. The recorder uses a reel which has standard IBM type hubs and can record for 30 hr on one reel of tape. At the end of the 30-hr period, as indicated by the hours-remaining dial on the recorder face, or whenever the operation history of the engine is required, the tape is removed and processed by a computer facility utilizing the Engine Analyzer Data Processing Program; this results in a printout of the operating parameters, trends, etc., for each of the flights on the tape. Table IX lists some of the important features of the recorder and its magnetic tape output.

TABLE IX

SIGNIFICANT RECORDER AND OUTPUT TAPE FEATURES

Tape speed	0.259 in./sec
Time per decimal digit word	1/144 sec
Parallel bits per word and parity	5
Words per channel	3
3-word channels per second	48
Words per inch	556
Continuous recording	57 sec
Blanking-gap	3 sec
Length of gap	0.819 in.
Tape width	0.500 in.
Tape length	2400 ft
Total recording period	[illegible] hr

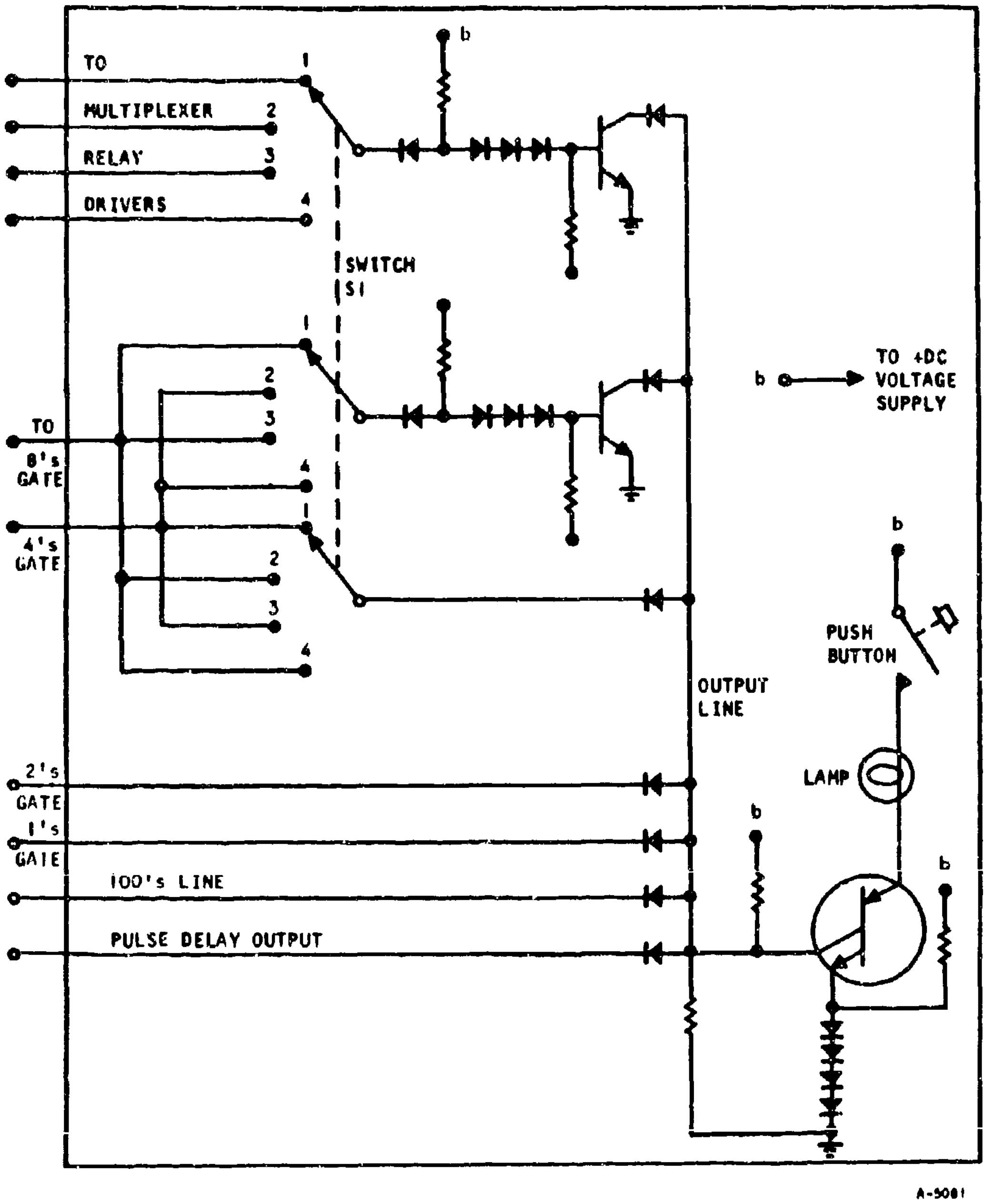


Figure 15. Signal Data Translator Self-Test Circuitry

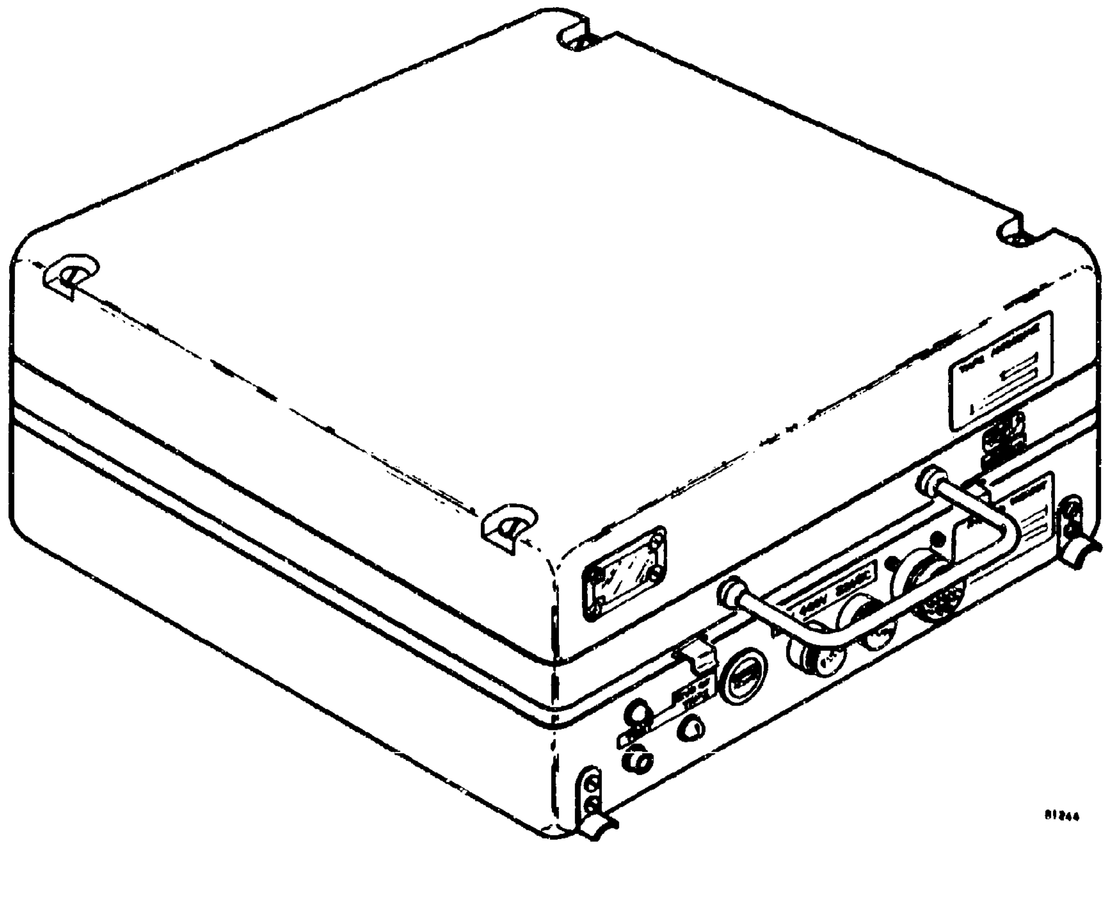


Figure 16. Engine Analyzer System Data Recorder, Isometric View

The Recorder consists of two separable units: the tape magazine, which contains the tape feed and take-up reels and recording heads, and the recorder base, which contains the electronics and the motor and tape drive mechanism. The recorder base is securely rack-mounted to the aircraft in the air turbine motor (ATM) compartment behind Access Door FF76. The tape magazine is removable from the front of the Recorder. Both units are separately housed in dust-proof and humidity-resistant enclosures. The tape magazine, which also serves as a transit container for the tape, has a magnetic shielding liner which provides protection against spurious external magnetic fields up to a magnitude of 50 gausses.

2.2.4.1 Recorder Theory of Operation

A functional diagram of the recorder is presented as Figure 17, showing both the electronic and mechanical portions of the recorder.

The record amplifiers are direct-coupled, solid-state stages, providing constant current to drive the magnetic heads. The timing reference is a 1440-cps tuning fork oscillator which controls the tape drive motor and also provides a 720-cps clock output to control the timing of the SDT. Power supplied to the recorder is both 28 v dc and 115 v, 400 cycle (single phase) ac. The d-c power is used for the motor drive circuits and the electronic functions; the a-c power drives the elapsed time indicator. The d-c power input is protected by transient suppressors which provide smoothing of aircraft-generated transients.

The tape transport mechanism is a capstan-driven, reel-to-reel device. The tape reels are mounted on the same axis for compactness, with the supply (unrecorded tape) reel mounted on the bottom and the take-up (recorded tape) reel mounted on the top. Take-up is accomplished on the take-up reel by a capstan-driven mylar belt driving the reel through a pulley-clutch combination. A clutch on the take-up reel compensates for the changing speed required as the reel fills with tape. On the supply reel, hold-back or drag is maintained by a static slip clutch. This drag prevents spillage from the supply reel as well as assuring taut guiding from reel to capstan. The capstan shaft is driven through a multi-jaw coupling between the magazine and the base. Drive power is provided by a 60-cps synchronous motor through a right-angle gear reduction designed to furnish the required tape speed of 0.259 in./sec.

2.2.4.2 Recorder Modules

The Recorder is designed using modular concepts for ease of maintenance.

2.2.4.3 Recorder Self-Test

The self-test function of the Recorder is actuated by the self-test pusnbutton on the front of the recorder, shown in Figure 16. Initiation of self-test by pressing this button results in two operations: one is the

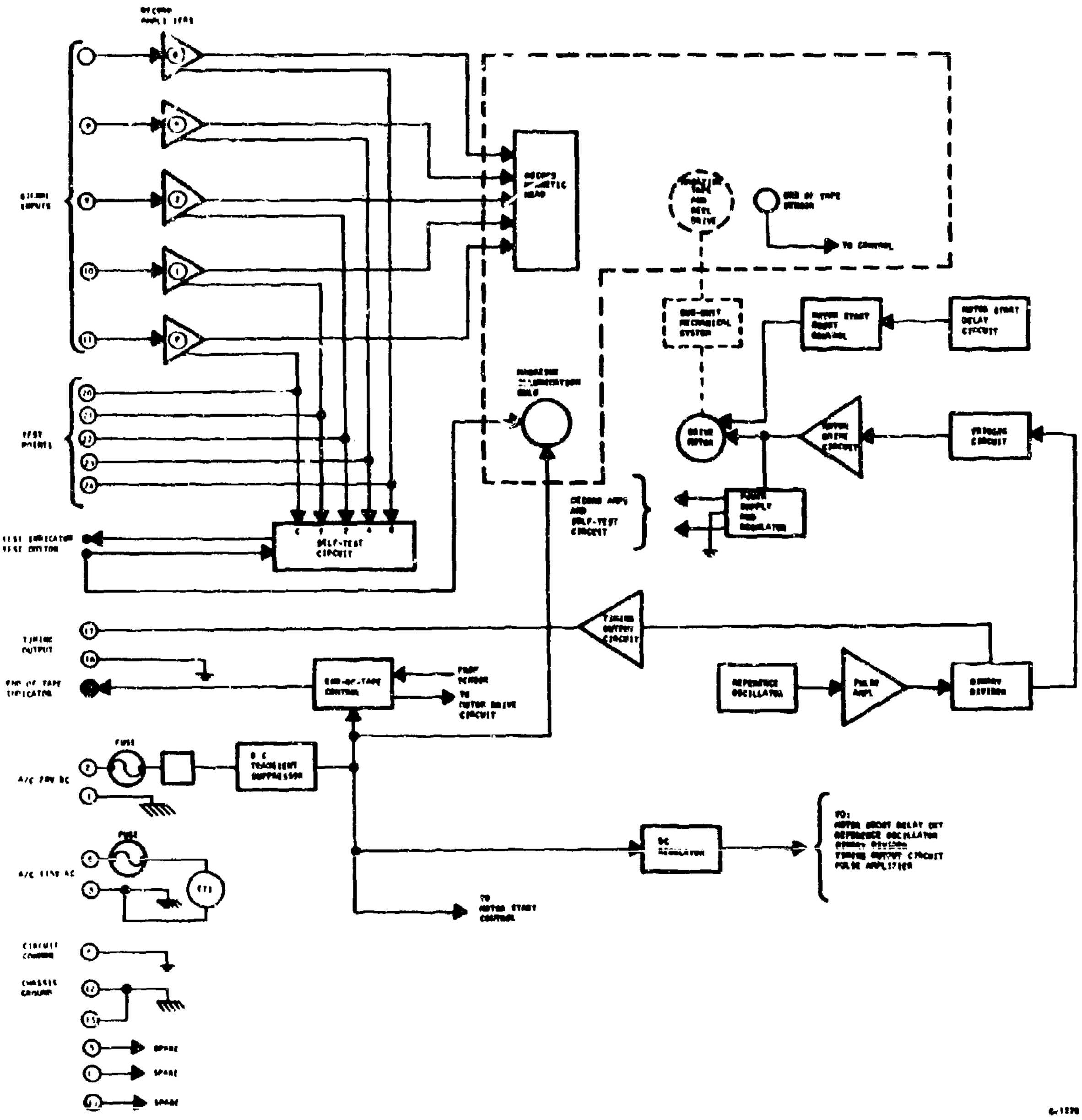


Figure 17. Recorder Functional Diagram

illumination of the interior of the tape magazine which allows the motion of the tape pressure roller to be observed. The recorder drive motor is a hysteresis synchronous device. This operation, then, serves as a test of the tape transport mechanism. The second operation initiated by actuation of self-test is a check of the recording amplifiers and heads. The self-test circuit samples the head drive current in each channel. If saturation current is present at each of the record heads during the 3-sec blanking gap period of the SDT, an AND gate provides an output which causes the self-test lamp on the front of the recorder to light steadily for a 3-sec period out of each minute, indicating the proper functioning of record circuitry.

2.3 Description of F-4C System

The F-4C Engine Analyzer System comprises two Computer/Displays, one Signal Data Translator, one Recorder, two sets of transducers, and interconnecting cables, pneumatic lines, and connectors. A complete list of the transducers is given in Table X; the table also presents salient characteristics of the system, including the part numbers, form-factor and weight of each of the major system components. The power requirements of the major system components are identical to those for the F-105D system (see Table II). Appendix II presents complete electrical circuitry schematic for the system components.

2.3.1 Transducers

The system includes a set of transducers which measure the temperatures, pressures, ON-OFF switch conditions, fuel flow, and speed (rpm), which will indicate changes of the engine operating conditions. The transducers are of the following types:

1. Variable reluctance transducers
2. Position variable resistance transducers
3. Temperature variable resistance transducers
4. Pressure switches
5. Temperature switches
6. Indicators (EGT)
7. Tach-generators
8. Synchro output transducers (EPR, fuel flow)
9. Relay contacts and limit switches

A list of the transducers used in the F-4C Engine Analyzer System is included in Table X. This table includes the weight and dimensions of major system components, in addition to the applicable AiResearch part number and Air Force Equipment Reference Number (AERNO). Succeeding paragraphs briefly describe the function of each transducer.

TABLE X

F-4C ENGINE ANALYZER SYSTEM DATA

System Components	Part Number	Size (Inches) height x width x depth	Weight (Pounds)
Computer/Display	538254-2-1	7 by 6.5 by 9.88	18.5
Signal Data Translator	538250-1-1	5.5 by 5.25 by 12.5	17.7
Recorder	538956	5 by 11 by 11	22.7 Δ
TRANSDUCERS			
Afterburner Switch*			
Anti-Ice Switch*			
Boundary Layer Control* Switch			
Compressor Discharge Pressure	538947-1		
Compressor Discharge Temperature	538952		
Compressor Inlet Pressure	538362-1-1		
Engine Pressure Ratio	61-2484**		
Exhaust Gas Temperature Indicator	538382		
Exhaust Nozzle Area (Pot)	538440-1-1		
Fuel Flow Transducer*			
Ignition Switch*			
Inlet Guide Vane (Pot)	538442-1-1		
Oil Pressure Switch	538957		

*F-4C engine analyzer system uses existing aircraft transducer

**Air Force Equipment Reference Numbers (AERNO)

ΔIncludes tape and reels

TABLE X (continued)

System Components	Part Number	Size (Inches) height x width x depth	Weight (Pounds)
Oil Pressure Transducer*			
Oil Sump Pressure	538947-3		
Oil Temperature Switch	538948		
Oil Temperature Transducer	802187-1		
Power Lever Angle	538444-1-1		
Spool Speed (N)*			
Inlet Total Temperature	60-1625**		

*Engine analyzer system uses existin., aircraft transducer

**Air Force Equipment Reference Numbers (AERNO)

2.3.1.1 Afterburner (A/B) Switch

The afterburner 115-v a-c signal to Computer/Displays one and two and the Signal Data Translator indicates that the A/B switch, actuated by a rise in fuel pressure, has been activated. AiResearch detection system is isolated from the aircraft afterburner system by an isolation relay.

2.3.1.2 Anti-Ice (A/I) Switch

The anti-ice 115-v a-c signal indicates that the A/I switch in the forward cockpit has been activated. The wiring diagram of the A/I system is found in Air Force Technical Manual T.O. IF-4C-2-23, page 3-41, Figure 3-17.

2.3.1.3 Boundary Layer Control (BLC) Switch

The boundary layer control switch provides a ground signal to the Engine Analyzer System that indicates that the two flap conditions, during which compressor bleed air is used for boundary layer control, are in effect. The two conditions are full-down and mid-way.

2.3.1.4 Compressor Discharge Pressure (P_{cd}) Transducer

This transducer measures absolute pressure at the discharge of the compressor. The transducer is a variable reluctance type with a range from 0 to 300 psia. The transducer output voltage varies from 0 to 500 mv at 400 cps for an input pressure change from 0 to 300 psia with a load of 20,000 ohms across the output. The output signal is supplied to the Signal Data Translator.

2.3.1.5 Compressor Discharge Temperature (P_{cd}) Transducer

The compressor discharge temperature transducer is a variable resistance element made of platinum wire, and has a temperature range of -100°C to +500°C with a nominal resistance of 50 ohms at 0°C. The probe tip has an applied operating pressure of 0 to 500 psia. The output is supplied to the SDT.

2.3.1.6 Compressor Inlet Pressure (P_{t_2}) Transducer

The compressor inlet pressure transducer utilizes a servoed force-balance sensor and provides outputs proportional to the natural logarithm of absolute pressure, switching action occurring at certain time-rates-of-change of the logarithm of absolute pressure, and a voltage proportional to absolute pressure.

2.3.1.7 Engine Pressure Ratio (EPR) Transducer

The EPR transducer is a pressure ratio synchro-style thrust transmitter (type MK-2). The output is supplied to the SDT Scott "T" transformer.

2.3.1.8 Exhaust Gas Temperature (EGT) Transducer

The exhaust gas temperature system consists of existing Chromel-Alumel thermocouple probes in the engine that actuate a single-point null-balancing type indicator in the cockpit. The indicator in turn provides four output signals to the engine analyzer. The four outputs are two pots and two switches; switch "A" closes at 982°C for hot start and switch "B" closes at 749°C for in-flight overtemperature; pot "1" is a log function of EGT and pot "2" is exponential function of EGT.

2.3.1.9 Exhaust Nozzle Area (ENA) Transducer

The exhaust nozzle area transducer consists of three ganged nonlinear pots, two 5000-ohm pots and one-1000-ohm pot, the positions of which are proportional to ENA. The pots are mechanically connected to the ENA Teleflex nozzle feedback linkage. Voltage ratios proportional to ENA are transmitted to the Computer/Display and to the Signal Data Translator.

2.3.1.10 Fuel Flow (Wf) Transducer

The fuel flow transducer is a remote indicating synchro-style rate of flow transmitter (Type T-6A). The synchro outputs feed the following:

a. An indicator with a range of 0 to 12,000 pph (Type A-19) in the cockpit

b. A control transformer in the Computer/Display fuel flow servo

2.3.1.11 Ignition Switch

The ignition switch signal is obtained from the cockpit ignition switch. The complete wiring diagram of the aircraft system is found in Air Force T.O. 1F-4C, Page 3-39, Figure 3-16.

2.3.1.12 Inlet Guide Vane (IGV) Transducer

The IGV transducer consists of three ganged nonlinear pots, two 5000-ohm pots and one 1000-ohm pot, the positions of which are proportional to IGV position. The transducer is mechanically connected to the IGV linkage in a manner similar to the feedback system. The voltage ratios proportional to IGV position are transmitted to the Computer/Display and the Signal Data Transducer.

2.3.1.13 Oil Pressure Switch

The oil pressure switch is a differential pressure-actuated switch used as a warning device to indicate the loss of turbine engine lubricating oil pressure. The switch provides a ground signal to the Computer Display upon loss of oil pressure.

The pressure switch has a pressure and vent port and is actuated by the pressure differential between ports. When oil pressure is 23 to 28 psid and above, a diaphragm in the switch housing maintains the switch contacts in the open position. When booster-pump pressure drops to 20 (±1) psid and below, the diaphragm closes the switch contacts, providing a ground circuit to the master caution control box. The pressure switch operates as follows: on increasing differential pressure, the switch will open the circuit at 23 to 28 psid and on decreasing differential pressure, the switch will close at 20 (±1) psid.

2.3.1.14 Oil Pressure (P_{oil}) Transducer

The oil pressure transducer is a synchro-style pressure transmitter (MH5). The output signals are supplied to an indicator in the cockpit and to the Signal Data Translator.

2.3.1.15 Oil Sump Pressure (P_{oil}sump) Transducer

The oil sump pressure transducer is a variable reluctance output type differential pressure sensor which indicates the proper functioning or malfunctioning of the engine by indicating the common sump to ambient air differential pressure.

2.3.1.16 Oil Temperature Switch

The oil temperature switch is a temperature-actuated switch used for indicating excessive oil temperature on the aircraft engine in flight. The switch provides a ground signal to the Computer/Display upon excessive temperature conditions.

2.3.1.17 Oil Temperature (T_{oil}) Transducer

The oil temperature transducer is a clamp-on and adhesive-bonded temperature transducer used for measuring the oil temperature of the aircraft engine in flight. The transducer output is a variable resistance signal supplied to the Signal Data Translator.

2.3.1.18 Power Lever Angle (PLA) Transducer

The power lever angle transducer is a single-turn precision linear variable resistor. The output goes to the Signal Data Translator.

2.3.1.19 Spool Speed (N) Transducer

The spool speed transducer N is a miniature electric three-phase, two-pole a-c tachometer-generator (GEU-7/A). The output signal goes to the Computer/Display and the cockpit indicators.

2.3.1.20 Total Temperature (T_{t2}) Transducer

The total temperature transducer is a dual-element total temperature probe capable of operating during atmospheric icing conditions. The dual elements are platinum wire, temperature-variable resistors which have a nominal resistance of 50 ohms at 0°C.

2.3.2 Computer/Display

The F-4C system employs two computer/displays, one for each engine of the F-4C. These units perform the same general functions as the F-105 computer/display and are identical to the latter units in external configuration. The F-4C computer/display, as described in the F-105 system description, presents red-flag indications when any of several engine parameters exceed predetermined limits.

The computer/display for the left hand engine is located in the forward cockpit in the left aft corner above the console. The computer/display for the right hand engine is also located in the forward cockpit in the right aft corner just above the carsole.

2.3.2.1 Computer/Display Operation

As in the case of the F-105 system, the computer/display mechanizes test cell and thermodynamic performance parameters to provide a go/no-go assessment at shutdown of gross engine health. The tests performed are the same as listed in Section 2.2.2.1 for the F-105.

The basis for and mechanization of the tests for the F-4C are essentially the same as described for the F-105 (Section 2.2.2). The principal differences are the test limits employed. The test conditions and limits for the F-4C computer/display are shown in Table XI. A signal flow diagram and functional block diagram of the computer/display were presented earlier as Figures 6 and 7. These diagrams idantify the elements peculiar to the F-4C computer/display and study of the diagrams provide a working knowledge of the operation theory of the computer/display.

Tables XII and XIII show the inputs, function ranges, and slew rates for the parameters for the referred fuel flow and engine temperature ratio computations.

2.3.2.2 Computer/Display Modules

The modular construction of the F-4C computer/display is identical to that for the F-105 and was shown earlier in Figure 7.

TABLE XI

COMPUTER/DISPLAY FLAG CHARACTERISTICS

Test	Test Condition	Failure Trigger Level
1. Slow start	Engine starting cycle from ignition or 10% rpm to 50% rpm; locked out thereafter	Greater than 55 sec
2. Fast stop	Engine shutdown 50% to 10% rpm	Less than 20 sec
3. Referred fuel flow	Steady-state engine operation, non-afterburning, non-water injection operation	$W'_{f\ meas} - W'_{f\ ref} > 0.10\ W'_{f\ ref}$
4. Engine temperature ratio	Steady-state engine operation, non-afterburning, non-water injection operation	$ETR_{meas} - ETR_{ref} > 0.06\ ETR_{ref}$
5. High EGT		
a. Hot start	Engine starting cycle to 90% rpm; locked out thereafter	Greater than 1800°F (982°C)
b. Operation	Sustained engine operation	Greater than 1380°F (749°C)
6. Engine overspeed		
a. Maximum	Any condition	Greater than 105% N_2
b. Normal	Any condition	Greater than 103.6% N_2 for over 1 min.
7. Low oil pressure	N_2 greater than 90%	Less than 21 psid
8. High oil temperature	Any condition	Greater than 300°F (149°C)
9. Expended hot section factors	EGT greater than 1572°R (600°C)	Accumulation

TABLE XII

J79-GE-15/F-4C REFERRED FUEL FLOW COMPUTER/DISPLAY INPUTS, FUNCTION RANGES, AND SLEW RATES

Input	Function	Source	Range	Slew Rate	Scale Factor
W_f	----	Fuel flow transmitter Type J-6A, per MIL-T-6598	200 to 12000 pph	NA	Synchro - 12.5 pph/deg to 3K pph 100 pph/deg above 3K pph
T'_{t_2}	----	Airframe total temperature probe, MIL-P-27723A, MIL-S 27188-2	390° to 1100°R	NA	Platinum wire with 50 Ω resistance 0°C
P_{t_2}		538362-1-1 Transducer	1.2 to 36 psia	Equivalent to Ln P_{t_2} Rate range in 1 min	
N	----	Aircraft tachometer, type R-88G	0 to 120 percent N_2		
$f_2(A_8)$	----	Nozzle area potentiometer	Equivalent to 2.0 to 5.0 sq ft	NA	
f_{10}(IGV)	----	IGV potentiometer	-16.5 to +19.5 deg	NA	
---	W_f	Computer/Display servo repeater	0 to 12,000 pph	2000 pph/sec	
---	T'_{t_2}	Computer/Display isolation transformer	390° to 1100°F	3°F/sec	
---	N	Computer/Display spool speed servo	0 to 120 percent N	25,000 rpm/min	
---	Ln N'	Computer/Display Ln N' servo	6000 to 8600 rpm	Compatible to N and T_{t_2} rate	
---	RNI	Computer/Display RNI servo	0 to 0.6	Compatible to P_{t_2} and T_{t_2} rate	

TABLE XIII

J79-GE-15/F-4C ENGINE TEMPERATURE RATIO COMPUTER/DISPLAY INPUTS, FUNCTION RANGES, AND SLEW RATES

Inputs	Function	Source	Range	Slew Rate
T'_{t_2}	----	Computer/Display isolation transformer	390° to 1100°F	3°F/sec
EGT	----	EGT indicator, modified MIL-I-27209-A	700 to 2350°R	
N	----	Aircraft tachometer, Type R-88G	0 to 120 percent N	----
P_{t_2}	----		1.2 to 36 psia	----
$f_8(A_8)$	----	Nozzle area potentiometer	Equivalent to 2.0 to 5.0 sq ft	NA
$f_9(IGV)$		IGV potentiometer	-16.5 to +19.5 deg	NA
----	T'_{t_2}	Computer/Display isolation transformer	390° to 1100°R	3°R/sec
----	P_{t_2}	Transducer	1.2 to 36 psia	Equivalent to Ln P_{t_2} Rate range in 1 min
----	N_2	Computer/Display	0 to 120 percent N	25,000 rpm/min
----	N'_2	Computer/Display N servo repeater	6000 to 8600 rpm	Compatible to N and T_{t_2} rate
----	RNI	Computer/Display RNI servo	0 to 0.6	Compatible to P_{t_2} and T'_{t_2} rate

2.3.2.3 Computer/Display Self-Test

Computer/Display Self-Test is actuated by the switch in the upper left corner of the computer/display face. Position 1 of the switch, marked NO TRIP, simulates a normal engine operating condition in the computer/display; none of the flags should drop during this phase of self-test. Position 2 of the self-test switch, marked TRIP, simulates an abnormal operating condition in the computer/display, during which all the flags must drop.

A schematic wiring diagram of the self-test circuitry is shown in Figure 18. When the self-test switch is turned to position 1, NO TRIP, a set of input signals corresponding to a typical engine operating condition is applied to the computer/display. These conditions are simulated by resistive divding networks. As mentioned above, none of the computer/display flags should drop. Position 2 of the self-test switch, TRIP, applies a set of signals corresponding to an abnormal operating condition. This is simulated by an improper spool speed signal for the other operating conditions. This abnormal condition will trip both the high consumption flag and the high engine temperature ratio flag. The remainder of the flags, which are switch operated, are tripped by the position 2 self-test circuitry. All the flags should, therefore, trip when the self-test switch is in position 2.

2.3.2.4 Computer/Display Calibration Adjustments

The controls for the calibration adjustments which adapt the computer/display for engine-to-engine variations and for transducer variations are the same as for the F-105 (Section 2.2.2.4).

2.3.3 Signal Data Translator

The characteristics and operation of the F-4C signal data translator are identical to those of the F-105 except for inputs and outputs. The characteristics of the inputs to the F-4C SDT are specified in Tables XIV and XV. The format of the F-4C SDT output is as shown in Table XVI. For all other aspects of the operation of this unit, refer to Section 2.2.3.

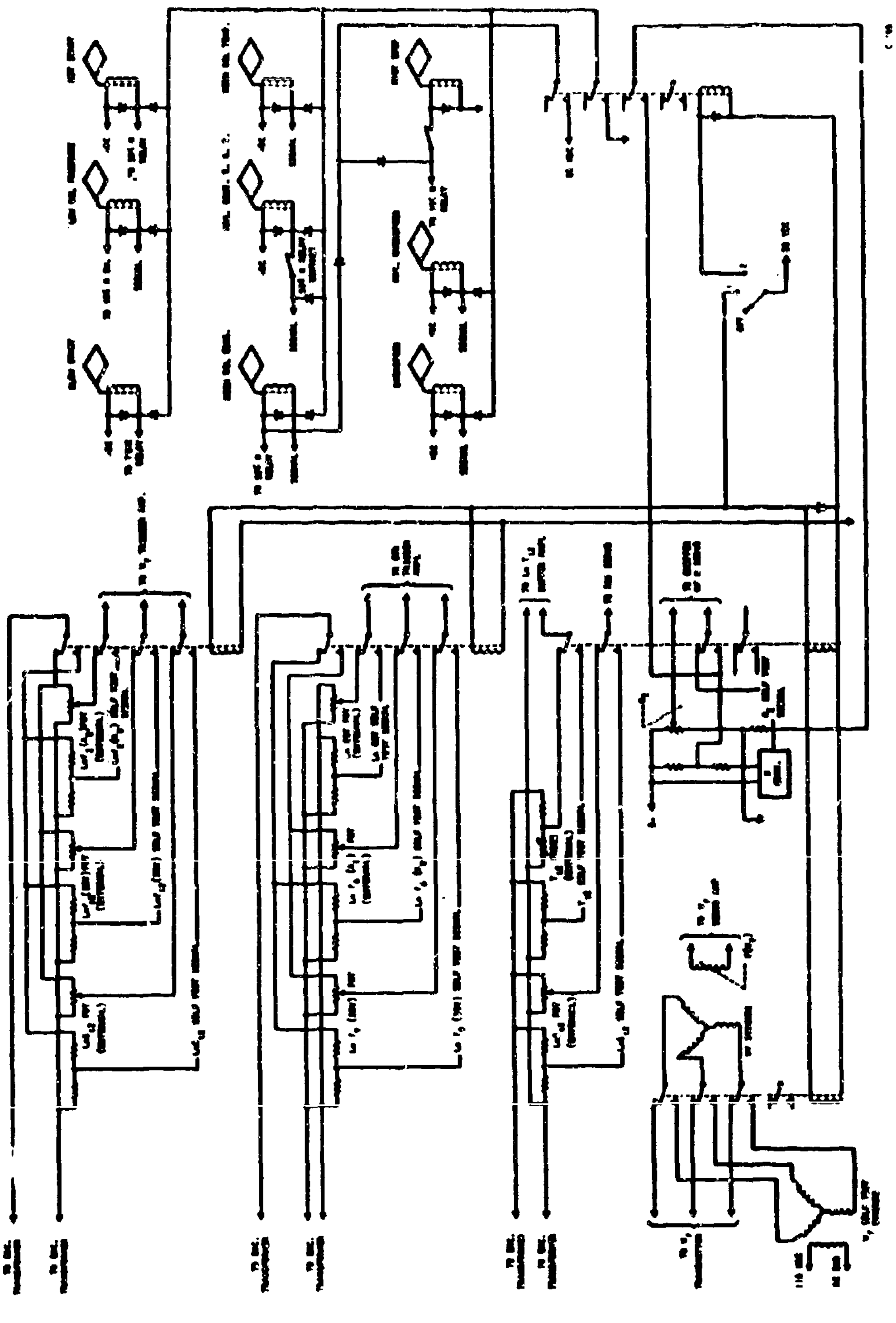


Figure 18. Computer/Display Self-Test Circuitry

TABLE XIV

F-4C SIGNAL DATA TRANSLATOR INPUTS

PARAMETER	CHANNEL Engine No. 1	CHANNEL Engine No. 2	SOURCE	DEVICE	RANGE
<u>Inlet Conditions</u>					
1. Inlet Total Temp (T_{t2})	10	18	C/D	AC Transformer	390° to 1100°R
2. Inlet Total Pressure (P_{t2})	27	33	A/C	DC Potentiometer	1.2 to 36 psia
3. Inlet Guide Vane Position	14	20	A/C	DC Potentiometer	−16.5° to +19.5°
<u>Compressor Conditions</u>					
1. Compressor Discharge Temperature	39	45	A/C	DC Resistance	600 to 1500°R
2. Compressor Discharge Pressure	17	23	A/C	AC Variable	0 to 310 psi
3. Spool Speed, N	15	21	C/D	DC Potentiometer	0 to 120% N
4. Anti-Ice On	—	—	A/C	Switch	—
5. BLC On	—	—	A/C	Switch	
<u>Fuel System</u>					
1. Power Lever Angle	2	8	A/C	DC Potentiometer	0–101°
2. Fuel Flow	19	25	C/D	DC Potentiometer	0–12,000 pph
<u>Turbine</u>					
1. Exhaust Gas Temperature	30	42	C/D	AC Transformer	700° to 2350°R
2. Engine Pressure Ratio	16 (Sin) 22 (Cos)	28 34	A/C	AC Synchro	1.2 to 3.4
3. Exhaust Nozzle Area	31	37	A/C	DC Potentiometer	260 to 710 in.²

PARAMETER	CHANNEL Engine No. 1	CHANNEL Engine No. 2	SOURCE	DEVICE	RANGE
<u>Lubrication System</u>					
1. Oil Temperature	38	44	A/C	DC Resistance Probe	−65 to +550°F
2. Oil Pressure					
MA-5	40 (Sin) 46 (Cos) Alternate		A/C A/C Seconds	AC Synchro	0 to 100 psid
3. Sump Pressure	29	35	A/C	AC Variable Reluctance	0 to 15 psia
<u>Initial Condition</u>					
1. Ignition On	—	—	A/C	Switch	—
2. Afterburner On	—	—	A/C	Switch	—
<u>Documentary Data</u>					
1. Aircraft Number	—	—	SDT	Thumbwheel Switches	—
2. Engine Number	—	—	SDT	Thumbwheel Switches	—
3. Flight Number	—	—	SDT	Thumbwheel Switches	—
4. Date	—	—	SDT	Thumbwheel	—

CODE: A/C — Aircraft
C/D — Computer/Display
SDT — Signal Data Translator

NOTE: All parameters are analog signals except switch functions

TABLE XV

PARAMETER FREQUENCY OF SIGNAL DATA TRANSLATOR OUTPUT
F-4C ENGINE ANALYZER SYSTEM

Once Per Sec Per Engine	Every 2 Sec Per Engine	First 20 Sec of Each Min
W_f	P_{oil}	20 digits of documentary data, one digit each second
EPR		
PLA		
T_{cd} (CDT)		
T_{t_2}		
EGT		
T_{oil}		
N		
P_{t_2}		
P_{oil}-sump		
IGN		
AB		
WI		
BLC		
ENA		
IGV		

2.3.4 Recorder

The F-4C and F-105 systems use the same recorder. See section 2.2.4 for a description of the recorder design and operation characteristics.

2.4 Ground Calibrator

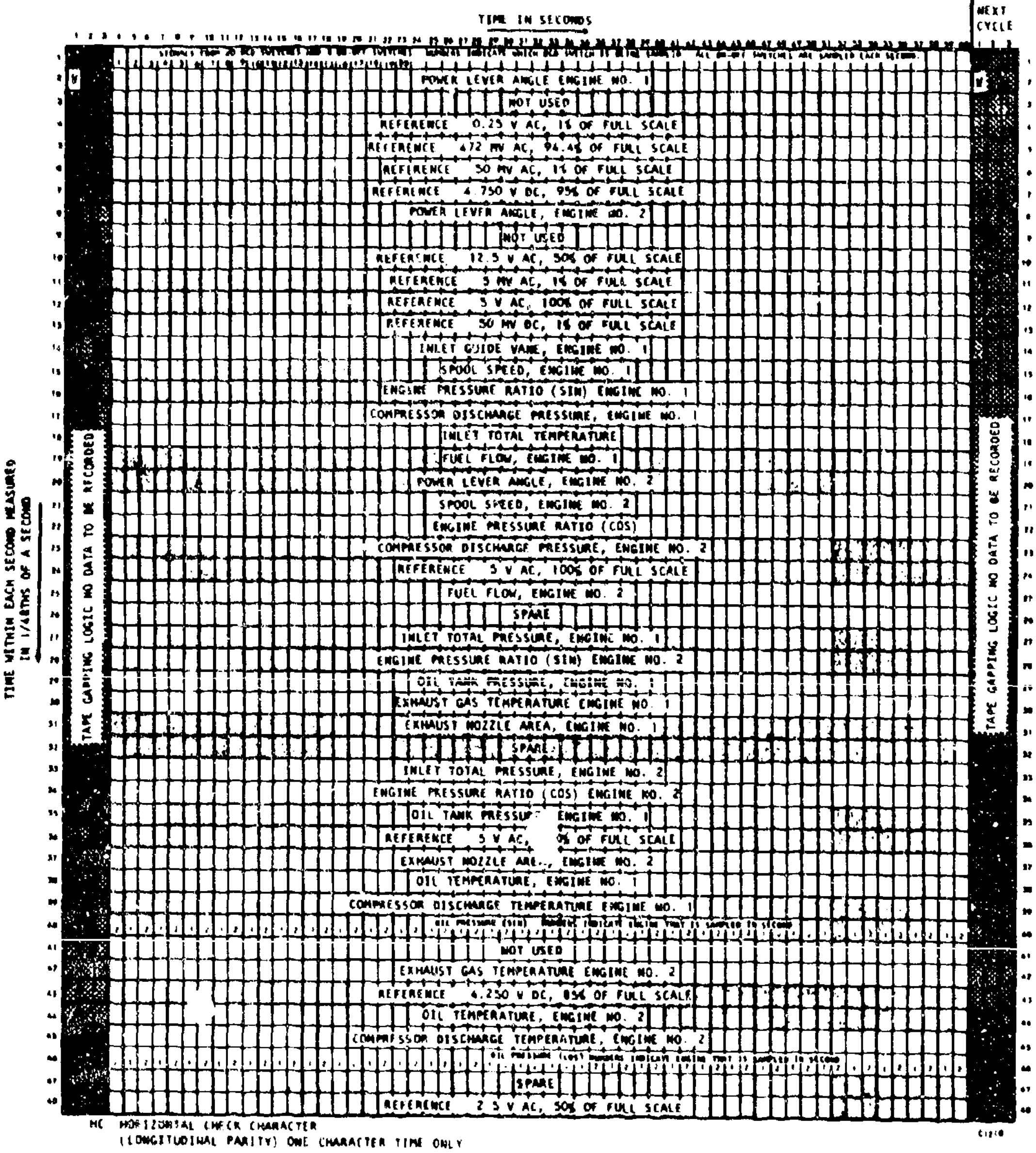
The Engine Analyzer Ground Calibrator P/N 538256-1-1 (Figure 19) provides ground support for the Engine Analyzer System. It is designed to check out and calibrate the Computer/Display, Signal Data Translator, and Recorder.

TABLE XVI

TIME SEQUENCE OF SDT OUTPUT

F-4C (J79 ENGINE)

THIS TABLE SHOWS WHAT SIGNALS ARE TO BE RECORDED IN EACH 1/48TH SECOND TIME SLOT DURING AN ENTIRE MINUTE. THE SIGNAL PATTERN IS IDENTICAL IN EACH SUCCESSIVE MINUTE.



HC HORIZONTAL CHECK CHARACTER (LONGITUDINAL PARITY) ONE CHARACTER TIME ONLY

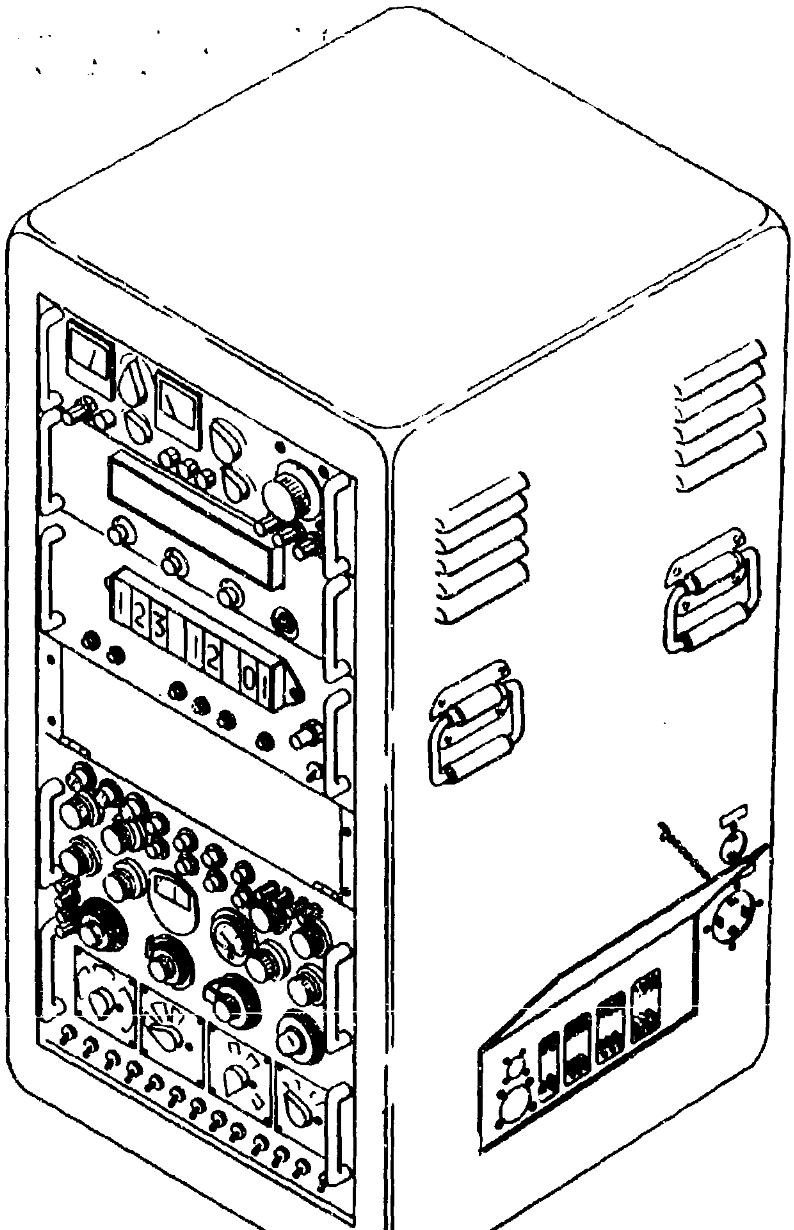


Figure 19. Engine Analyzer Ground Calibrator

In addition, all submodules requiring calibration can be calibrated and checked by the simulated inputs provided by the calibrator. Any combination of the Computer/Display, Signal Data Translator, or Recorder may be operated simultaneously. Appendix III presents the electrical circuitry schematic of the ground calibration.

With the exception of the GFAE tachometer tester TTU-27/EC, the externally supplied cables and holding fixture, all simulated inputs, and all readouts required are contained within the basic unit.

External equipment is necessary only during troubleshooting; the external equipment needed is a Tektronix oscilloscope Model 555 or equivalent and an a-c voltmeter, Hewlett-Packard Model 400H or equivalent. The calibrator is contained in one chassis and requires only 115-v, 400 cps, 3-phase, and 28-v d-c power to furnish flight line or shop level test capability for the analyzer system. The calibrator provides all the power necessary to drive any portion of the engine analyzer system under test. The alternating current supplied to the various components of the calibrator and to the component being tested is accurately controlled by a self-contained 3-phase Variac. Provisions are included for an external adjustable d-c power supply whenever variable direct current is required.

A block diagram of the Ground Calibrator is shown in Figure 20. The outputs which the calibrator furnishes for the Computer/Display checkout provide stimuli which can be varied over the entire range of the Computer/Display functions. The calibrator simulates the switch inputs to the Computer/Display, such as high oil temperature, by furnishing the required ground or 28-v d-c signal; the variable functions, such as P_{t_2}, are simulated by potentiometers.

For checks of spool speed over the range, a GFAE tachometer tester, Consolidated Airborne Systems TTU-27/E, is used in conjunction with the calibrator. Testing of parameters other than spool speed is all done at one of three discrete rpm values for N: 50 percent, 85 percent, or 100 percent. These values supplied to the Computer/Display are tuning-fork controlled for maximum accuracy.

Fuel flow input is provided to the Computer/Display by a synchro. Variable over the fuel flow range, the synchro is adjusted by a synchro-positioner.

A self-contained ratiometer is used to check fuel flow and spool speed signals from potentiometers on the respective servo shafts in the Computer/Display. The calibrator contains a Dekatran to check the total temperature and exhaust gas temperature signals from the transformer windings in the Computer/Display. A self-contained transistorized a-c VTVM is used for null indication.

A switch is provided for the Computer/Display elapsed engine time indicator. This allows verification of proper indicator operation, after which the indicator is switched off to prevent the accumulation of indicated engine time during ground testing.

NOT REPRODUCIBLE

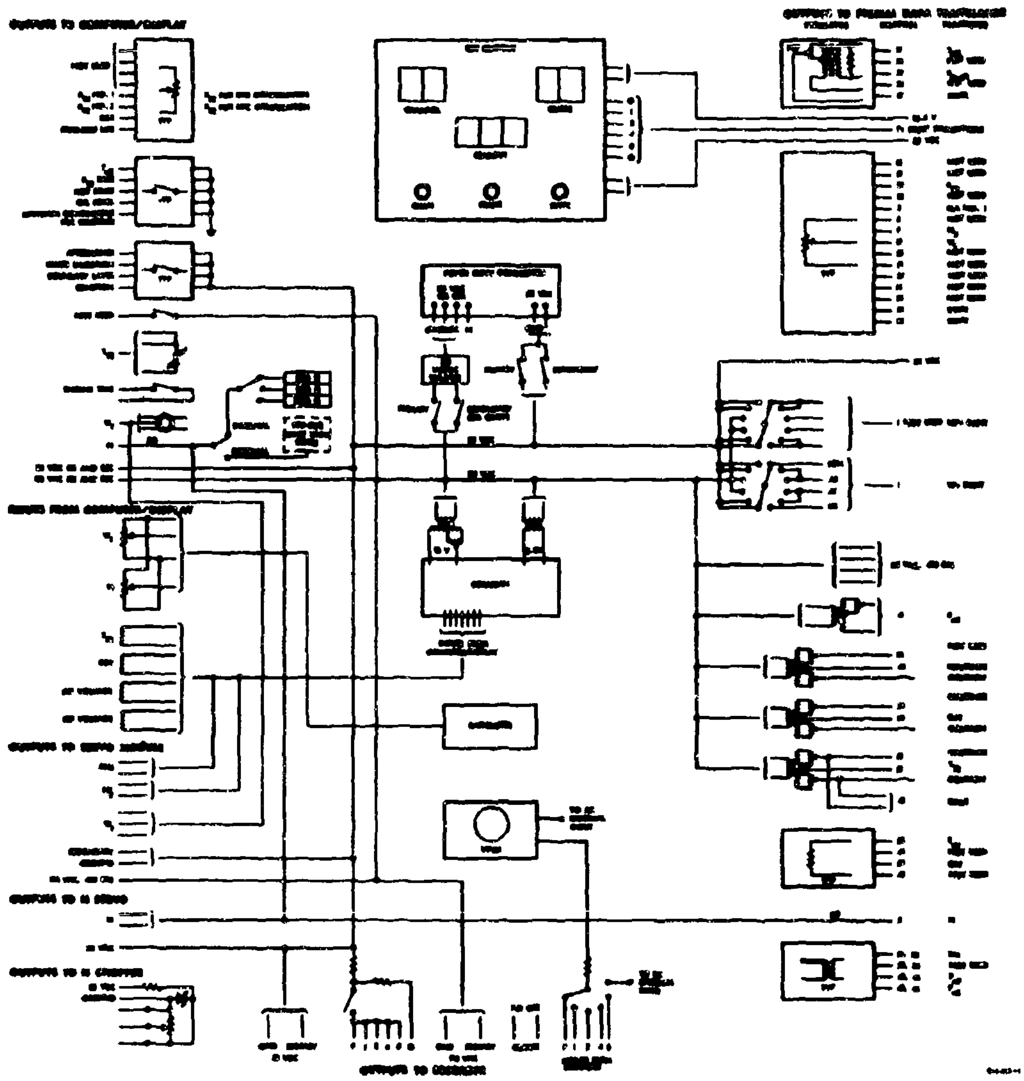


Figure 20. Engine Analyzer Ground Calibrator Block Diagram

Provisions are included in the calibrator for testing the Computer/Display spool speed module and the servo module. Energizing dc and a spool speed signal are provided to the N module for its checkout. A highly accurate adjustable d-c signal is provided to simulate the N converter and directly drive the chopper in the spool speed loop. The calibrator provides to the servo module the necessary power, a fuel flow signal to the W_f control transformer, and signals for the Reynolds number index and N_g servo follow-up potentiometers.

All inputs to the Signal Data Translator are fixed signal points simulated by resistive dividers, tapped transformers, switches, and fixed resistors. The gains on each input are staggered to detect any shorts between channels. The staggered points also provide an indication of the linearity of the individual active elements. Provisions for the calibration of the analog-to-digital converter module are included. A readout panel is provided which presents the number and output of the channel being checked. Frame number is also presented to allow stepping through 20 48-channel frames to check each of the thumbwheel switch outputs. The channel and frame advance functions gate a free-running oscillator to the Signal Data Translator clock input. Internal calibrator logic counts the output pulses to provide the SDT with the required number of pulses for channel and frame advance.

To check the recorder, the calibrator provides a 9-v signal to each of the recorder inputs, in addition to the required power. A test point from each of the record heads is brought out, and the VTVM in the calibrator is used to see that there is current of sufficient magnitude and proper phase flowing in each head. The 720-cps clock signal is also checked by the calibrator by means of a small electronic counter and meter.

2.4.1 Calibrator Sub-Units

The ground calibrator is physically arranged in five separate panels which are shown in Figure 21. Each panel and its accompanying chassis is considered an individual subunit of the calibrator. The top panel is the power supply subunit; the second is the ratiometer; and the third contains the SDT readouts and the controls for stepping through the channels and frames of the SDT. The chassis of the fourth panel, which is blank, holds the logic cards for the SDT readout circuitry. The bottom panel is the switching panel and contains the controls for the parameter simulation that the calibrator supplies to the Engine Analyzer System. On the lower right side of the cabinet are the connectors for the power required by the calibrator, and, behind a hinged door, are the connectors for the system components and modules.

Each of the five basic panels is removable from the front. A detailed description of each panel follows.

a. Power Panel--The power panel controls the 28-v d-c and 115-v, 400-cps, three-phase power for unit checkout. The panel contains meters for monitoring, control switches, pilot lights, adjustments, and fusing for the 28-v d-c power and the three-phase, 115-v a-c power. The fuses have pilot lamps which light when a fuse blows. There is a four-position control switch for both the d-c and a-c supplies.

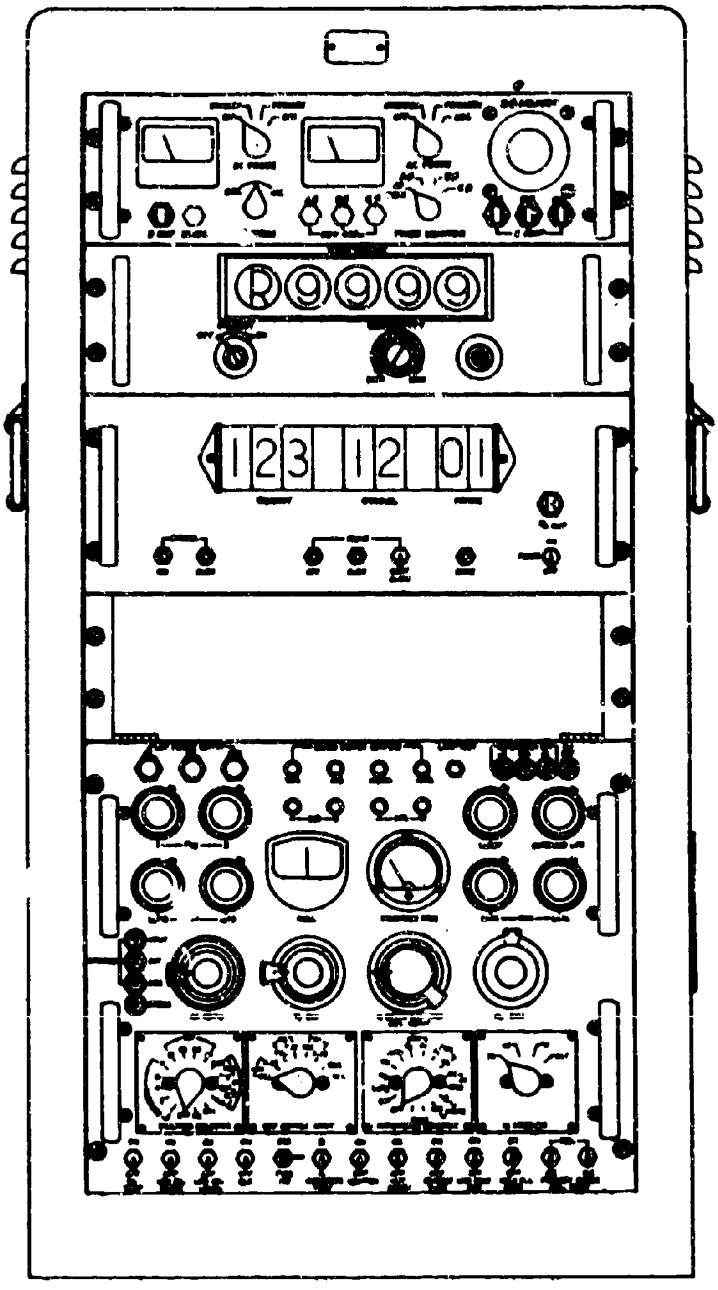


Figure 21. Ground Calibrator Face

The a-c power switching arrangement is identical to the d-c switching. The ac, in addition, is adjustable by means of a three-phase Variac and a trim adjustment for the A-phase. The ac is monitored by pilot lights for each phase and an expanded-scale voltmeter which can be switched to each phase or to monitor the A-phase trimming. Each phase is fused for 2 amps. The "OFF" positions remove power from the units completely. The "STANDBY" position supplies power to the ratiometer, readout, and the logic panels only. The "PRIMARY" position supplies power to the Computer/Display for checkout of "essential" circuits only. The "SEC" position supplies the power required by the modules, any combination of Computer/Display, Signal Data Translator, and Recorder.

The d-c voltmeter is used to monitor the 28-v d-c bench supply, while the expanded scale a-c meter monitors the three-phase output of the three-phase adjust Variac by means of the phase monitor switch. The "AØ TRIM" control acts as a vernier on the A-phase voltage when the Signal Data Translator is being tested. This control adds or subtracts a small voltage from the A-phase and is monitored on the a-c meter when the "PHASE MONITOR" switch is in "AØ TRIM" position. Front panel fuses and power lamps are also provided. Accessory power connectors are located on the rear of the chassis with access through the rear cabinet door.

b. Ratiometer--The ratiometer is an ESI model 4000-3182 which functions both as a ratiometer and digital voltmeter. All controls for operation are located on the front panel. Inputs to the ratiometer are controlled by the "RATIOMETER SELECTOR" switch located on the switching panel.

c. Readout Panel--The readout panel contains all the control circuitry for the various operational modes of the Signal Data Translator and a visual readout device which displays the individual channel readouts (000 to 999), the channel (0 to 48) and frame counts (01 to 60). A separate power switch and fuse are provided. The "Sync" switch (which must be depressed at the start of each checkout) is used to synchronize the calibrator to the Signal Data Translator.

The channel "ADV" switch will advance the Signal Data Translator one channel each time it is depressed. The readout and channel will visually appear in the readout window. The channel "SLEW" switch permits rapid access to any of the 48 input channels.

The frame "ADV" switch will advance the Signal Data Translator one frame (48 channels) each time it is depressed. The number of the frame will visually appear in the frame readout window. The frame "SLEW" and "CONT SLEW" switches permit rapid access to any of the 60 frames during testing or troubleshooting.

A block diagram of the readout logic is presented in Figure 22. The channel and frame advance switches gate free-running 600-cps and 800-cps oscillators, respectively, to the counter logic and the SDT. When the required number of pulses for the desired advance have passed, the clock gates are closed and the frame and channel number are digitally displayed. The SDT output is read, converted from non-return-to-zero to decimal, the parity computed, and then displaced.

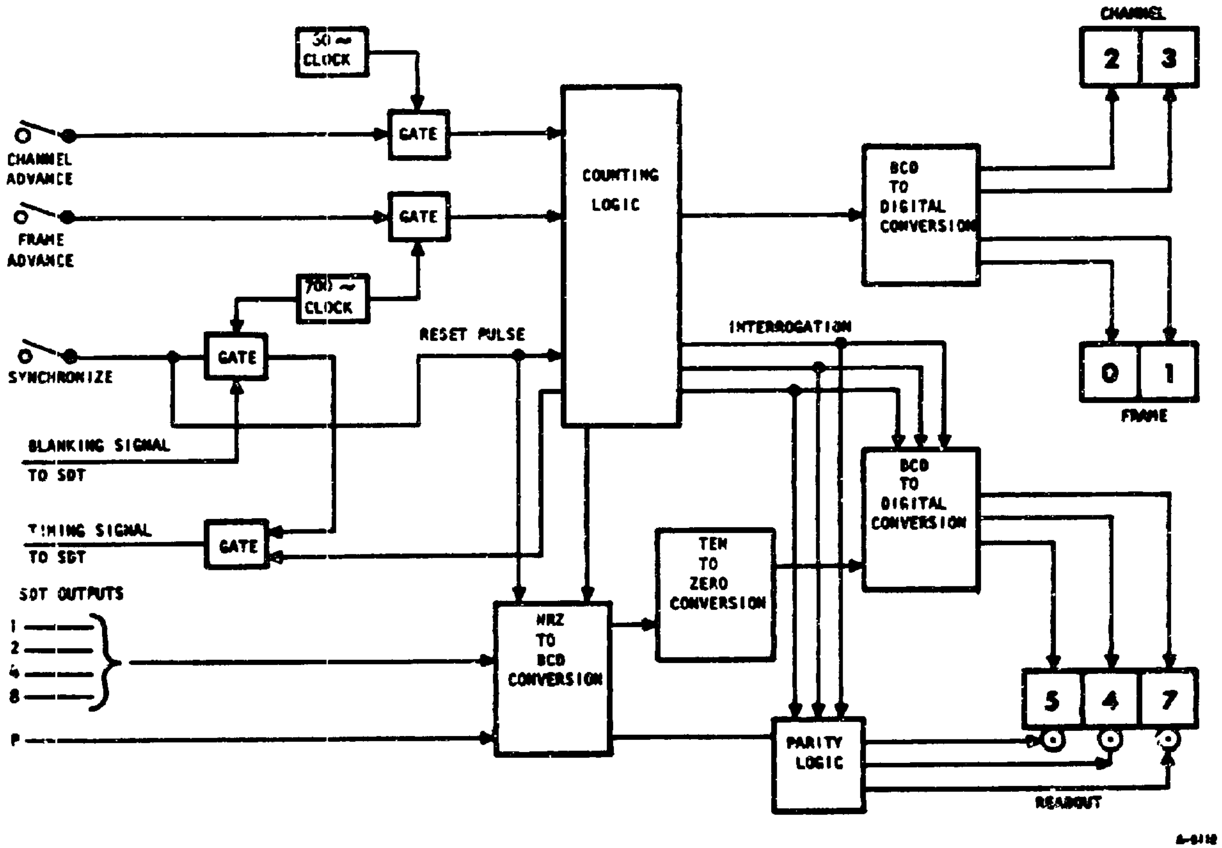


Figure 22. Block Diagram of Ground Calibrator SDT Readout

d. <u>Logic Panel</u>--The logic panel converts the NRZ logic output of the Signal Data Translator into decimal form which drives the visual display on the readout panel. Operator control is provided by the readout panel.

e. <u>Switching Panel</u>--The switching panel provides the simulated inputs and required readouts for the modules, Signal Data Translator, Recorder, and Computer/Display. Each control, beginning left top, left to right, will be discussed below.

The "SDT Power Output" lamps "AC," "DC," and "GRD," indicate that proper power is available from the SDT for driving the recorder.

The eight lamps labeled 7.5 percent through 105 percent, check switch closure when the Computer/Display "N Servo" module is being tested or calibrated.

The "Lamp Test" switch is a self-test of the eight lamps previously described.

The "Ratiometer EXT" and "10V REF" jacks allow external use of the ratiometer when the "Ratiometer Selector" is in "EXT" position.

The "Ln P_{T2} (1 and 2)," "IGV (Ln F^{10} and Ln F^{9})," "ENA (Ln f_2 and Ln f_4)," "Ln EGT" and "Expended Life" are 10-turn precision potentiometers used to simulate inputs to the Computer/Display.

The "NULL" meter is used with the "AC RATIO" ratiotran when reading the inputs shown for the "Recorder," "SDT," and "CD" on the "Function Selector" switch.

The "Recorder Frequency" is a self-contained digital counter which checks the Recorder clock frequency during Recorder testing.

The "Ratiotran" and "Bridge" test jacks allow external use of the "AC Ratio" ratiotran and "NULL" meter when the "Function Selector" is in "EXT" position.

The "AC RATIO" ratiotran is a five-place a-c voltage divider used to read out all positions shown on the "Function Selector" switch except N$\frac{1}{2}$ and RNI positions. In these two positions, ratioed voltages are supplied to the N$\frac{1}{2}$ and RNI servo modules for calibration of the W_f, N$\frac{1}{2}$, RNI servo module.

The "T_T Sim" is a precision, five-place resistive network designed to simulate the total temperature probe during Computer/Display checkout and calibration.

The "N Servo Command and ADC Input" simulator is a precision, five-place resistive divider used to provide d-c voltage ratios when testing either the Computer/Display "N Servo Module" or the SDT "ADC" module. Its use is controlled by the "N and ADC IN" positions of the "Ratiometer Selector" switch.

The W_f simulator is a precision 10-turn Acton positioner driving a synchro which simulates fuel flow. The output is used by the Computer/Display, and the W_f, N_2^1, RNI Computer/Display servo module.

The "Function Selector" switch selects and routes the inputs and outputs of the "AC RATIO" ratiotran and "NULL" meter. When testing the Recorder, positions 1, 2, 4, 8, and P read out acceptable limits of recorder head currents on the "NULL" meter. At each position, the "Recorder Test" switch is actuated from "A" to "B" position. This checks that the record amplifiers provide current reversals. Positions E1, E2, E3, and E4 are used to measure the a-c transducer excitation on the "AC RATIO" ratiotran and "NULL" meter when testing the SDT, Positions "EGT and T_{T_2} REF" and "EGT and T_{T_2} OUT" are used to measure the C/D outputs to the SDT on the "AC RATIO" ratiotran and "NULL" meter when testing the Computer/Display. The remaining three positions were discussed under "AC RATIO" ratiotran.

The "SDT SWITCH INPUT" switch simulates aircraft switch functions as indicated on the switch plate. These are used when testing the Signal Data Translator.

The "Ratiometer Selector" selects all inputs for the ratiometer. N_2 and Ln N_2 are used during N module calibration. W_f, Ln W_f, RNI (f_3 and f_7), and N_2 (f_1 and f_5) are used during calibration of the W_f, RNI, N_2^1 servo module. Positions were previously discussed under "N Servo Command" and "Ratiometer", respectively. "N Volts" is used to monitor the N rate lockout signal during Computer/Display checkout. The "ADC VOLTS" is used to check the 5-v d-c reference when calibrating the ADC.

The "N FREQ SIM" provides three precision frequency points for checkout of the SDT and C/D. An "Ext" position is provided to use the GFAE TTU-27/E tachometer tester as a test input.

All 13 toggle switches, except for the "Recorder Test" previously described, are used as marked during checkout of the Computer/Display.

All connector receptacles are located on the switching panel chassis and are accessible through an access door on the lower right side of the calibrator cabinet.

In addition to the front panel controls described previously, the chassis contains all the simulated inputs for the SDT. These inputs consist of fixed-gain, precision-calibrated, resistive dividers, transformers, and resistors. The characteristics of each are described in Tables XVII and XVIII under Accuracy.

2.4.2 Simulator Characteristics and Accuracy

The important characteristics and accuracies for all the simulated inputs required by the Engine Analyzer System are tabulated below. These are divided into two groups (1) front panel variable functions which have been previously described and are used mostly for Computer/Display checkout and calibration; and (2) the fixed-gain simulated inputs for SDT.

TABLE XVII

FRONT PANEL FUNCTION

Function	Device	Accuracy	Comment
D-c power	Meter	2%	-
A-c power	Meter	0.2% FS	Expanded meter calibrated at 115 v
Ratio	Ratiometer	±0.0% full scale plus 0.002% per °C from 25°C	-
D-c voltage	Ratiometer	±0.01% full scale plus 0.002% per °C from 25°C	-
Readout and logic panels	Digital	No error	-
P_{T2} (1)	10T potentiometer	±0.1% FS	-
P_{T2} (2)	10T potentiometer	±0.1% FS	-
Ln EGT	10T potentiometer	±0.1% FS	-
Expended life	10T potentiometer	±0.3% FS	-
EGV Lnf10	10T potentiometer	±0.2% FS	-
IGV Lnf9	10T potentiometer	±0.3% FS	-
ENA Lnf2	10T potentiometer	±0.1% FS	-
ENA Lnf6	10T potentiometer	±0.1% FS	-
Null	Meter	±0.5 mv	-
Recorder freq	Digital circuit and meter	0.1% at 720 cps	-
A-c ratio	Ratiotran	±0.002% FS	-
T_T SIM	Dekastat	±0.5°R	-
ADC input	Dekastat	±0.1% FS	-

TABLE XVII (continued)

Function	Device	Accuracy	Comment
W_f SIM	Synchro and positioner	±0.2 deg	-
N FREQ SIM	Tuning fork oscillator	±0.02% of frequency	Fixed frequency points at 35, 63, and 70 cps

TABLE XVIII

FIXED SDT FUNCTIONS
(INTERNAL TO CALIBRATOR)

Function	Device	Fixed Output or Gain Setting	Setting Accuracy
W_f No. 1	Resistive Divider	0.010	±0.2% ind
W_f No. 2	Resistive Divider	0.120	±0.2% ind
A_8 No. 1	Resistive Divider	0.140	±0.2% ind
A_8 No. 2	Resistive Divider	0.160	±0.2% ind
A_8 No. 2	Resistive Divider	0.160	±0.2% ind
PLA No. 1	Resistive Divider	0.500	±0.1% ind
PLA No. 2	Resistive Divider	0.520	±0.1% ind
IGV No. 1	Resistive Divider	0.540	±0.1% ind
IGV No. 2	Resistive Divider	0.560	±0.1% ind

TABLE XVIII (continued)

Function	Device	Fixed Output or Gain Setting	Setting Accuracy
Spare CH 26	Resistive divider	0.570	±0.1% Ind
Spare CH 32	Resistive divider	0.580	±0.1% FS
T_{oil} No. 1	Resistive	0.50	±0.1% FS
T_{oil} No. 2	Resistor	0.1[illegible]0	±0.1% FS
N_1 J75	Tuning fork oscillator	35 cps 63 cps 70 cps	±0.2- of frequency point
N_2 J75	Resistive divider	0.900	±0.1 Ind
N J79 No. 1	Resistive divider	0.920	±0.1% Ind
N J79 No. 2	Resistive divider	0.940	±0.1 Ind
P_{T2} No. 1	Resistive divider	0.960	±0.1% Ind
P_{T2} No. 2	Resistive divider	0.990	±0.1% Ind
CDT No. 1	Resistor	0.099	±0.2% FS
CDT No. 2	Resistor	0.050	±0.2% FS
EPR No. 1	Transformer	EZ 120 deg	±0.25% Ind
EPR No. 2	Transformer	EZ 240 deg	±0.25% Ind
P_{oil} No. 1	Transformer	EZ 0 deg	±0.25% Ind
P_{oil} No. 2	Transformer	EZ 300 deg	±0.25% Ind

TABLE XVIII (Continued)

Function	Device	Fixed Output or Gain Setting	Setting Accuracy
P_{cd} No. 1	Transformer	0.450 v ac	±0.25% ind
P_{cd} No. 2	Transformer	0.225 v ac	±0.25% ind
$P_{D\ oil}$ No. 1	Transformer	0.045 v ac	±0.35% ind
$P_{D\ oil}$ No. 2	Transformer	0.005 v ac	±0.5% ind
$P_{D\ oil}$	Transformer	12.95 v ac	±0.25% ind
Spare CH 47	Transformer	0.450 v ac	±0.25% ind
T_{T2} ref	Transformer	4.50 v ac	±0.25% ind
T_{T2} out	Transformer	2.50 v ac	±0.25% ind
EGT No. 1 ref	Transformer	4.50 v ac	±0.25% ind
EGT No. 1 out	Transformer	3.25 v ac	±0.25% ind
EGT No. 2 ref	Transformer	4.50 v ac	±0.25% ind
EGT No. 2 out	Transformer	1.25 v ac	±0.25% ind

APPENDIX I

CIRCUIT SCHEMATICS FOR F-105D ENGINE ANALYZER SYSTEM

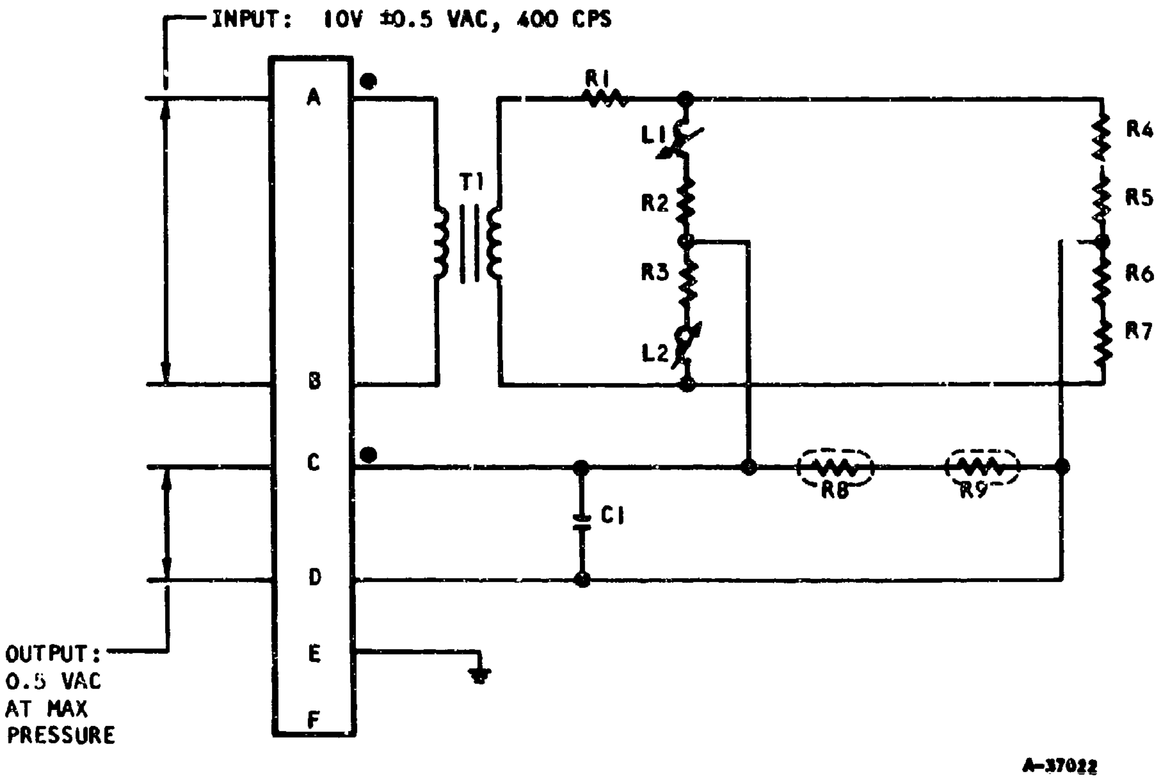


Figure 23. Oil Breather Pressure (P/N 538947-2) and Compressor Discharge Pressure (P/N 538947-1) Transducer Circuit Schematic

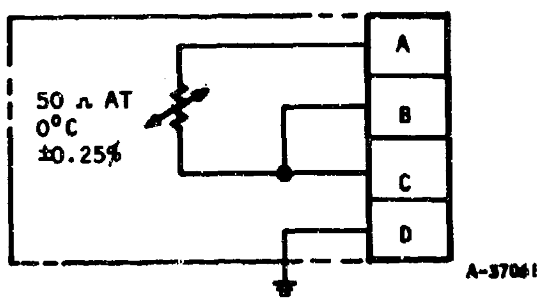


Figure 24. Compressor Discharge Temperature Transducer (P/N 538952) Circuit Schematic

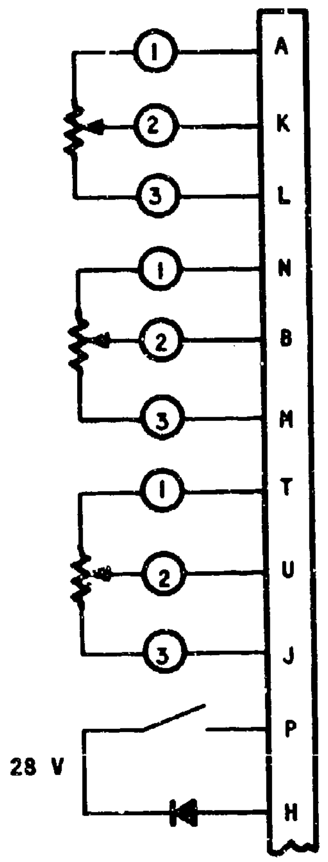


Figure 25. Compressor Inlet Pressure Transducer
(P/N 538962-1-1) Circuit Schematic

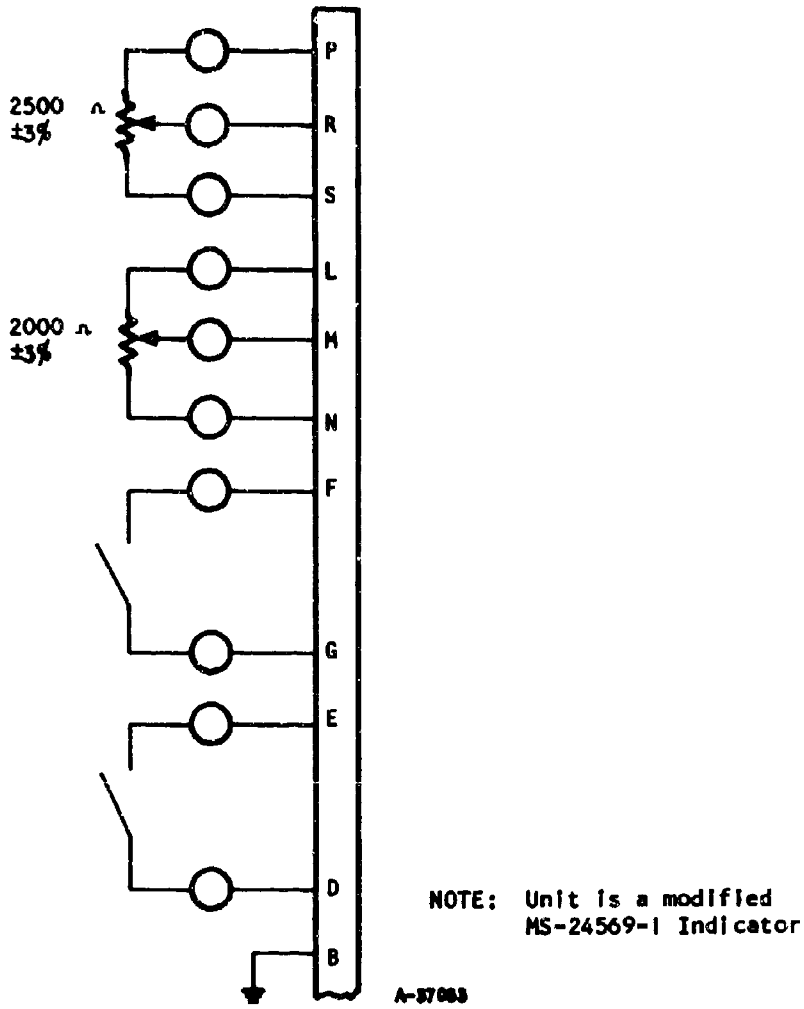


Figure 26. Exhaust Gas Temperature Transducer (P/N 538380) Circuit Schematic

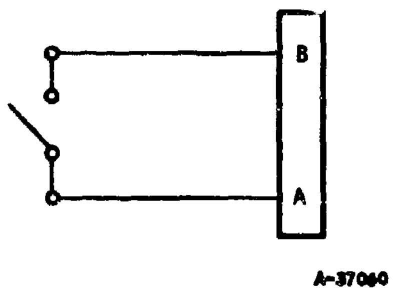


Figure 27. Oil Temperature Switch (P/N 538948) Circuit Schematic

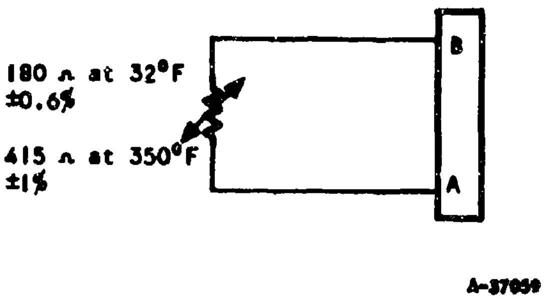


Figure 28. Oil Temperature Transducer (P/N 538950) Circuit Schematic

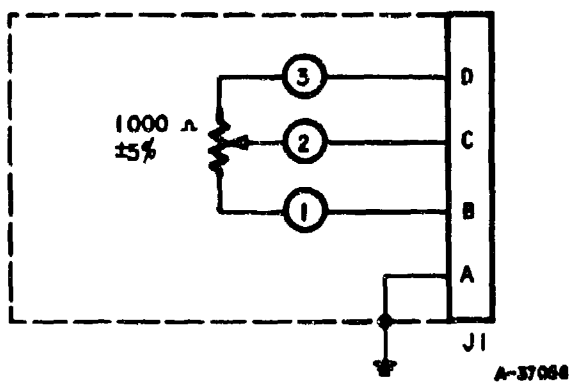
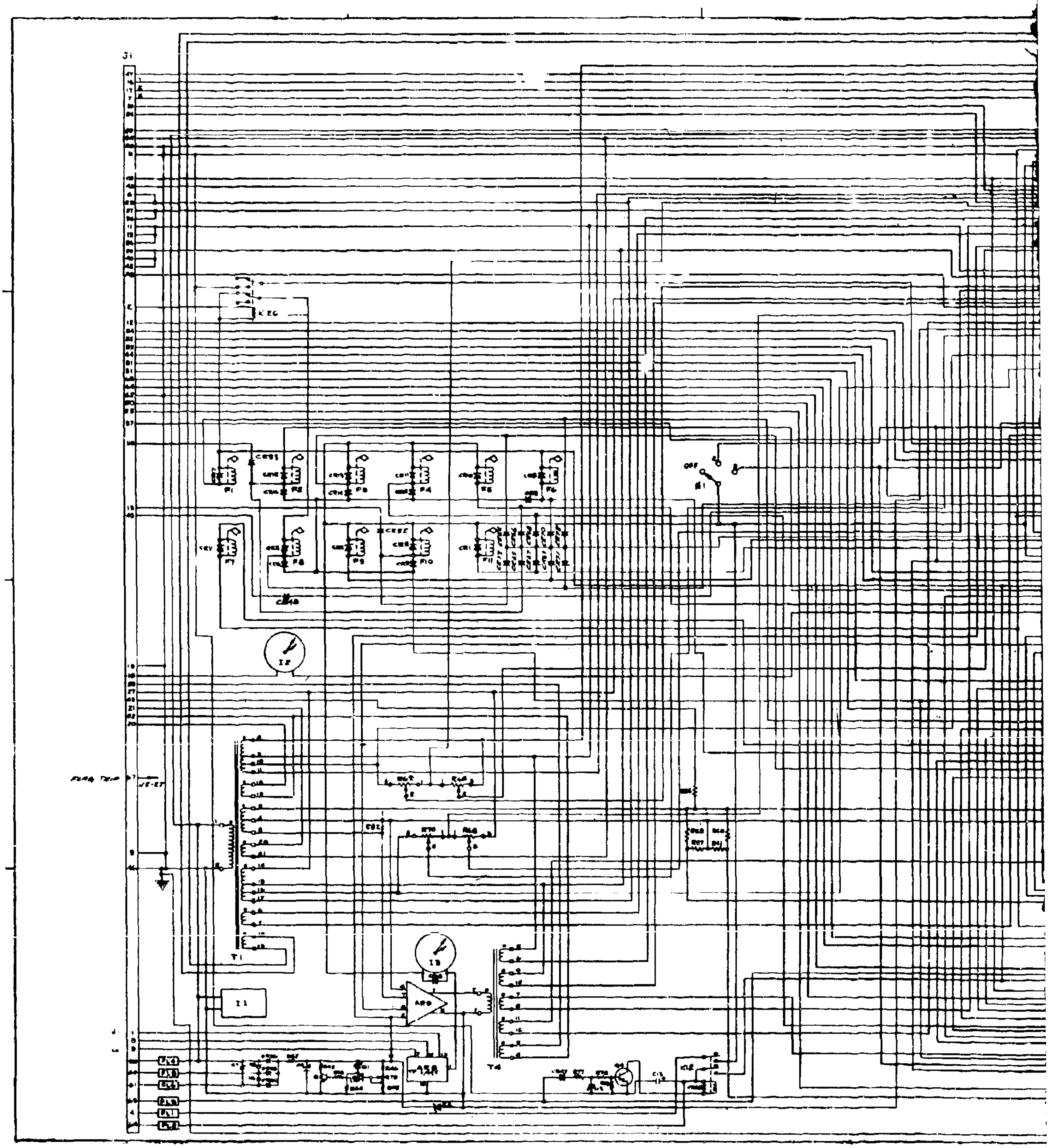


Figure 29. Power Lever Angle Transducer (P/N 538444-1-1)
Circuit Schematic



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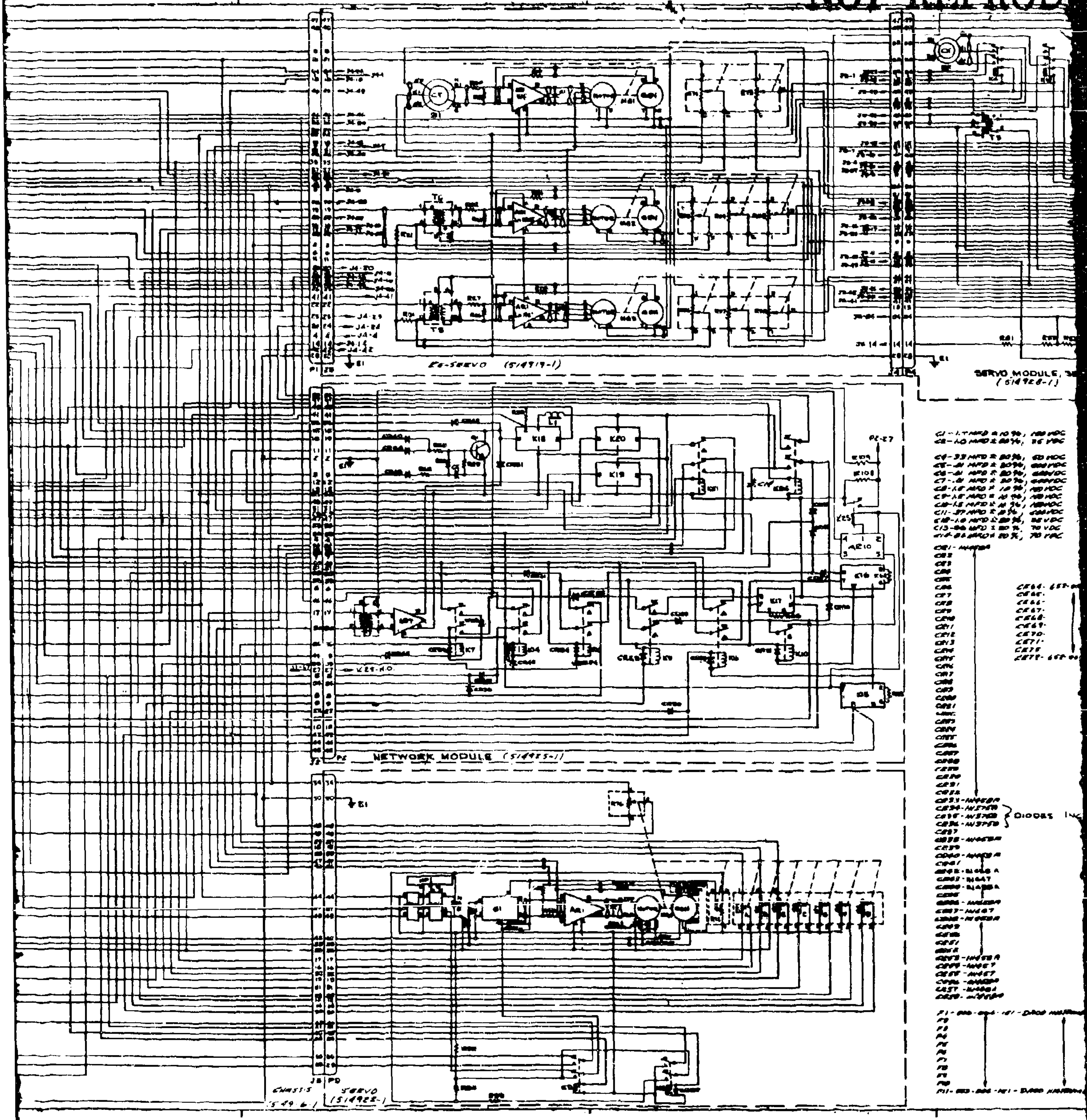
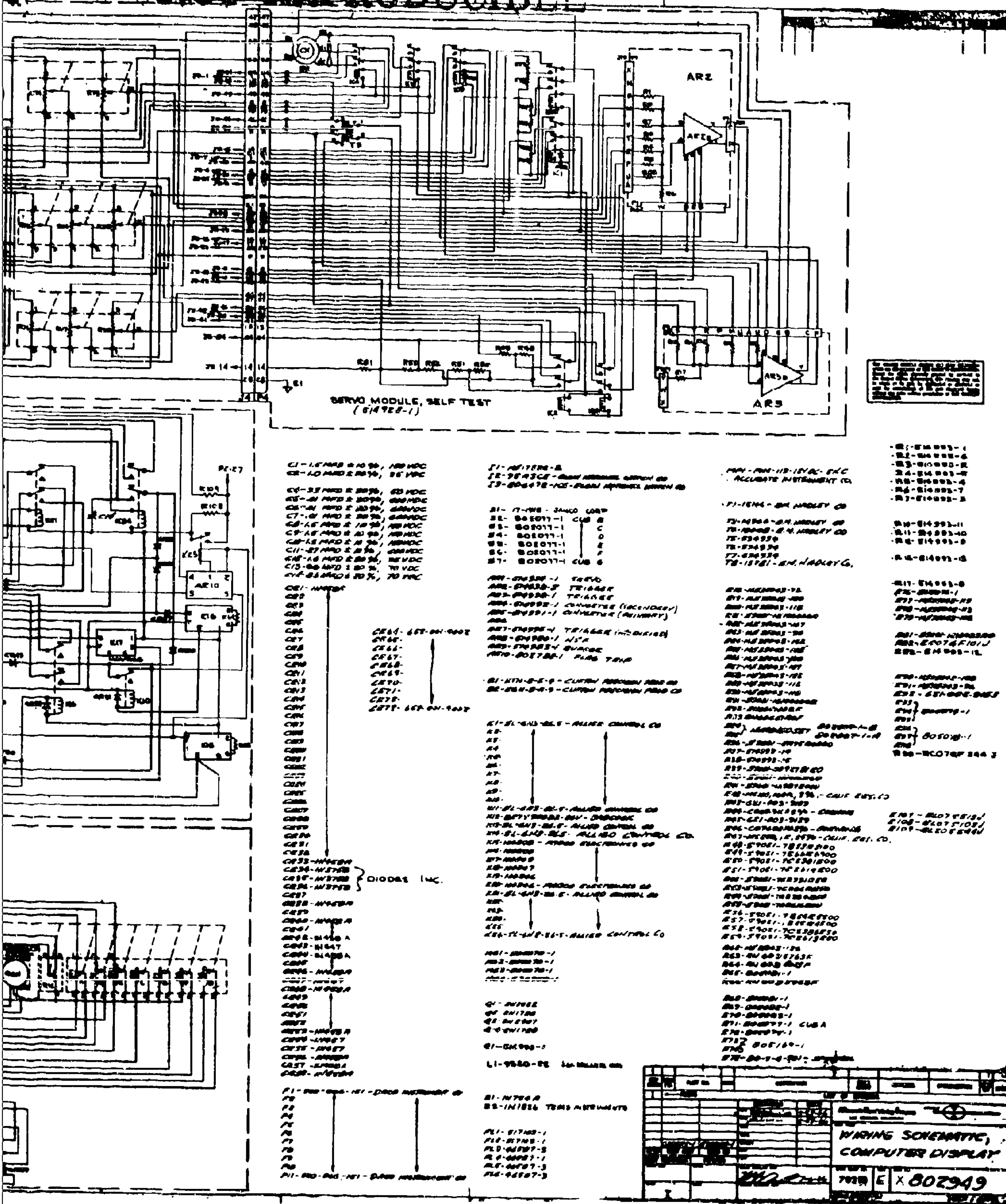


13


AR2
AR3
SERVO MODULE, SELF TEST
(614928-1)
DIODES INC.
WIRING SCHEMATIC,
COMPUTER DISPLAY
X 802949

NOT REPRODUCIBLE

AR1 COMPONENT LIST

COMPONENT	PART NO.	REMARKS
R1	MS35043-116	
R2	MS35043-111	
R3	MS35043-27	
R4	MS35043-[illegible]	
R5	MS35043-80	
R6	MS35043-27	
R7	MS35043-[illegible]	
R8	[illegible]	[illegible]
R9	[illegible]	
R10	621-[illegible]	
R11	MS35043-[illegible]	
R12	621-002-[illegible]	
R13	[illegible]	
C1	[illegible]	PER SPEC MIL-C-[illegible]
C2	[illegible]	PER SPEC MIL-C-[illegible]
C3	[illegible]	PER SPEC MIL-C-[illegible]
C4	[illegible]	PER SPEC MIL-C-[illegible]
C5	190-001-9001	
C6	[illegible]	PER SPEC MIL-C-[illegible]
Q1	2N[illegible]	[illegible]
Q2	2N[illegible]	[illegible]
Q3	2N[illegible]	PER SPEC MIL-S-[illegible]
CR1	[illegible]	[illegible]
T1	[illegible]	[illegible]
P1	[illegible]	MFG BY CONTINENTAL CONNECTOR [illegible], N.Y. [illegible]

AR4 COMPONENT LIST

COMPONENT	PART NO.	REMARKS
R1	MS35043-[illegible]	MIL-R-11
R2	MS35043-[illegible]	MIL-R-11
R3	MS35043-[illegible]	MIL-R-11
R4	C-07 [illegible]	MFG BY CORNING
R5	C-07 [illegible]	MFG BY CORNING
R6	C-07 [illegible]	MFG BY CORNING
R7	C-07 [illegible]	
R8	MS35043-[illegible]	MIL-R-11
R9	[illegible]	MFG. BY CORNING
R10	[illegible]	MIL-R-11
R11	[illegible]	MIL-R-10509
R12	[illegible]	MIL-R-10509
R13	[illegible]	MIL-R-10509
R14	[illegible]	[illegible]
R15	[illegible]	MFG. BY CORNING
R16	621-003-[illegible]	
R18	C-07 [illegible]	MFD BY CORNING
R19	C-07 [illegible]	MFD BY CORNING
R21	C-07 [illegible]	MFD BY CORNING
R22	C-07 [illegible]	MFD BY CORNING [illegible]
R23	C-07 [illegible]	FED SUPPLY CODE NO. [illegible]
R24	C-07 [illegible]	
R25	C-07 [illegible]	
R26	[illegible]	
T1	PIP-[illegible]	UNITED TRANSFORMER CO. LOS ANGELES, CALIF. FED. SUPPLY CODE [illegible]
C1	[illegible]	MFG. BY SPRAGUE
C2	CTOD-471K	MFG. BY GULTON IND., INC.
C3	CTOD-[illegible]	
C4	[illegible]	MFG. BY SPRAGUE
C5	[illegible]	MFG BY GULTON INDUSTRIES, INC METUCHEN, N. J. FED SUP CODE [illegible]
C6	CTOD-471K	ALTERNATE FOR C7
C7	[illegible]	[illegible] N.Y.
C8	[illegible]	[illegible]
C9	CTOD-101K	MFG BY GULTON IND. INC
C10	[illegible]	MFG BY SPRAGUE [illegible], MASS. FED. SUPPLY CODE [illegible]
L1	[illegible]	[illegible]
CR1	1N758A	MFG BY TEXAS INSTRUMENTS
CR2	1N[illegible]	[illegible]
CR3	1N758A	
CR4	1N645	MFG. BY TEXAS INSTRUMENTS, DALLAS, TEXAS FED. SUPPLY CODE 56214
CR5	1N758A	
CR6	1N914A	
CR7	1N758A	
CR8	1N914A	
CR9	1N487	[illegible]
CR10	1N914A	MFG BY TEXAS INSTRUMENTS
CR11	1N487	MFG. BY CONTINENTAL DEVICE
CR12	1N758A	MFG. BY TEXAS INSTRUMENTS
CR14	1N758A	
CR16	1N487	MFG BY CONTINENTAL DEVICE
Q1	2N2221	MFG. BY MOTOROLA
Q2	2N2221	
Q3	2N2221	
Q4	2N2221	
Q5	2N[illegible]	MFG BY MOTOROLA
Q6	2N2221	MFG. BY MOTOROLA
Q7	2N2221	
Q8	2N[illegible]	MFG BY TEXAS INSTRUMENTS
Q9	2N[illegible]	
C15	[illegible]	MFG BY SPRAGUE
C16	[illegible]	
C17	CTOD-101K	MFG BY GULTON IND INC
C18	CTOD-471K	
P1	[illegible]	MFG BY CONTINENTAL CONNECTOR [illegible] N.Y. FED [illegible]

AR5 COMPONENT LIST

COMPONENT	PART NO.	REMARKS
R1	621-[illegible]	
R2	621-00[illegible]	
R3	621-00[illegible]	
R4	C-07 [illegible]	MFG. BY CORNING, BRADFORD, PA. FED SUPPLY CODE [illegible]
R5	C-07 [illegible]	
R6	C-07 [illegible]	
R7	MS35043-[illegible]	MIL-R-11
R8	C-07 [illegible]	MFG. BY CORNING
R9	C-07 [illegible]	
R10	C-07 [illegible]	
R11	MS35043-[illegible]	MIL-R-11
R12	C-07 [illegible]	MFG. BY CORNING
R13	MS35043-[illegible]	MIL-R-11
R14	MS35043-[illegible]	
R15	C-07 [illegible]	MFG. BY CORNING
R16	MS35043-[illegible]	MIL-R-11
R17	C-07 [illegible]	MFG. BY CORNING
R18	C-07 [illegible]	
C1	[illegible]	MFG. BY SPRAGUE
C2	CT100-102K	MFG. BY GULTON IND. INC.
C3	[illegible]	MFG. BY SPRAGUE, [illegible] FED. SUPPLY CODE
C5	[illegible]	
C6	[illegible]	
C7	[illegible]	[illegible]
C8	[illegible]	MFG. BY SPRAGUE
C9	CTOD-[illegible]	MFG BY GULTON IND. INC. METUCHEN, N.J. FED SUPPLY CODE [illegible]
C10	CTOD-101K	
CR1	1N758A	MFG. BY TEXAS INSTRUMENTS, DALLAS, TEXAS FED SUPPLY CODE 56214
CR2	1N758A	
CR3	1N758A	
CR4	1N487	MFG. BY CONTINENTAL DEVICE
CR5	1N758A	MFG. BY TEXAS INSTRUMENTS
CR6	1N487	MFG. BY CONTINENTAL DEVICE
CR7	1N758A	MFG. BY TEXAS INSTRUMENTS
CR8	1N487	MFG. BY CONTINENTAL DEVICE, [illegible]
CR9	1N487	FED SUPPLY CODE 07910
Q1	2N2222	MFG. BY MOTOROLA, PHOENIX, ARIZONA FED SUPPLY CODE 04713
Q2	2N2221	
Q3	2N2221	
Q4	2N2221	
Q5	2N2221	
Q6	2N2221	
P1	[illegible]	MFG BY CONTINENTAL CONNECTOR [illegible] N.Y. FED [illegible]
T1	[illegible]	[illegible]

AR2a, AR3a COMPONENT LIST

COMPONENT	PART NUMBER	REMARKS
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MFG. BY KEMET, CLEVELAND, OHIO FED. SUPPLY CODE [illegible]
C9		▲
C10		▲

AR7 COMPONENT LIST

COMPONENT	PART NUMBER	REMARKS
[illegible]	[illegible]	[illegible]
R15	C-07 [illegible]	
R16	C-07 [illegible]	
R17	C-07 [illegible]	
R18	C-07 [illegible]	
[illegible]	[illegible]	MFG BY TEXAS INSTRUMENTS, DALLAS, TEXAS, FED SUPPLY CODE [illegible]
[illegible]	1N758A	MFG. BY MOTOROLA
[illegible]	[illegible]	MFG. BY CONTINENTAL DEVICE HAWTHORNE, CALIF. FED. SUPPLY CODE 07910
[illegible]	2N2907	
[illegible]	2N2222	

AR7 (CONT.)

COMPONENT	PART NO.	REMARKS
AR7	[illegible]	[illegible]
P1	[illegible]	[illegible]

AR8

COMPONENT	PART NUMBER	REMARKS
[illegible]	[illegible]	[illegible]
PLATE	EM049	

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AR7 (CONT)	
PART NO.	REMARKS
[illegible]	MFG BY CORNING
[illegible]	[illegible]

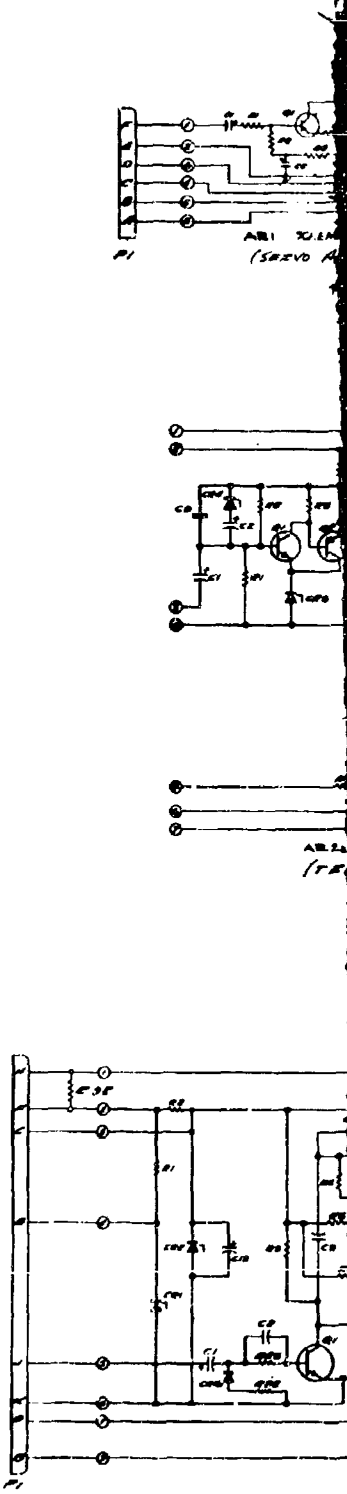
AR8 (CONT)		
COMP	PART NO.	REMARKS
R20	[illegible]	MFG BY SPECTROL ELECTRONIC CORP. SAN GABRIEL, CALIF. FED. SUPPLY CODE 02111
R21	[illegible]	
R22	[illegible]	

AR6	PARTS LIST	
		REMARKS
[illegible]	[illegible]	[illegible]

AR9 COMPONENT LIST		
COMPONENT	PART NO.	REMARKS
R1	[illegible]	MFG. BY [illegible], BRADFORD, PA. FED. SUPPLY CODE 07116
R2	[illegible]	
R3	[illegible]	
R5	[illegible]	
R7	[illegible]	
R8	[illegible]	MIL-R-10509
R10	[illegible]	
R11	[illegible]	
C1	[illegible]	MFG. BY SPRAGUE, NORTH ADAMS, MASS. FED. SUPPLY CODE 56289
C2	[illegible]	
C3	[illegible]	[illegible]
C4	[illegible]	MFG. BY SPRAGUE
C5	[illegible]	
C6	[illegible]	
C8	CT100-100K	MFG BY [illegible]
C9	[illegible]	
CR1	[illegible]	MFG. BY MOTOROLA, PHOENIX, ARIZONA FED. SUPPLY CODE [illegible]
CR2	[illegible]	
CR3	[illegible]	[illegible]
Q1	[illegible]	MFG. BY TEXAS INSTRUMENTS DALLAS, TEXAS FED SUPPLY CODE [illegible]
Q2	[illegible]	
Q3	[illegible]	

Q1 COMPONENT LIST		
COMPONENT	PART NO.	REMARKS
R1	[illegible]	
R2	[illegible]	
Q1	2N3569	AMPEREX ELECTRONIC CO. HICKSVILLE, N.Y. FED CODE 73445
Q2	2N2369	
T1	[illegible]	[illegible]
T2	14699A	[illegible]

AR10 COMPONENT LIST		
COMPONENT	PART NO.	REMARKS
R1	[illegible]	MIL-R-11
R2	[illegible]	
R3	[illegible]	
R4	[illegible]	
R5	[illegible]	
R6	[illegible]	
R7	[illegible]	
R8	[illegible]	
C1	[illegible]	MIL-C-[illegible]
CR1	[illegible]	
CR2	[illegible]	
CR3	[illegible]	
CR4	[illegible]	
CR5	[illegible]	
CR6	[illegible]	
CR7	[illegible]	
CR8	[illegible]	
CR9	[illegible]	
CR10	[illegible]	
CR11	[illegible]	
CR12	[illegible]	
Q1	[illegible]	
Q2	[illegible]	
Q3	[illegible]	
Q4	[illegible]	
Q5	[illegible]	MIL-S-19500/[illegible]

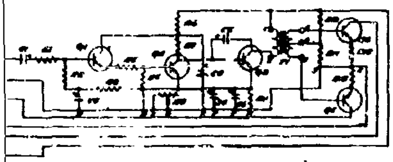


X802949 | 1

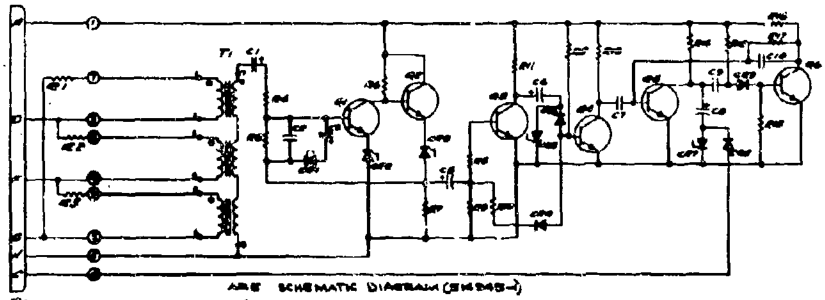
8 | 7 | 6

B

5 4 3



AR1 SCHEMATIC DIAGRAM (SK4936-1)
(SERVO AMP)



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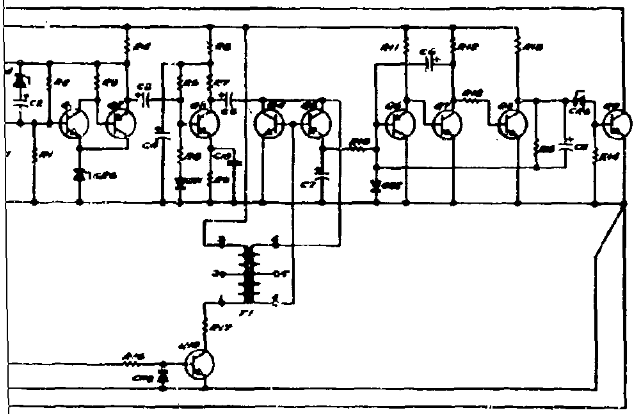
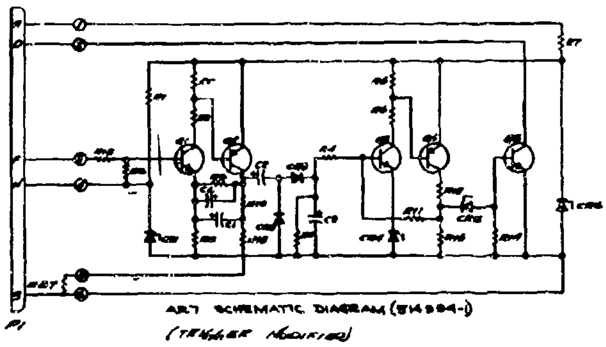
(CONVERTER, PRIMARY)



AR2, AR3 SCHEMATIC DIAGRAM (SK4940-1)
(TRIGGER)



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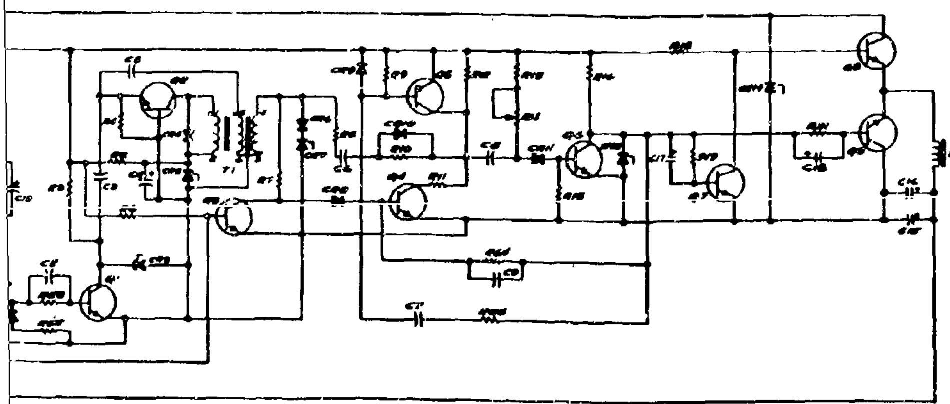

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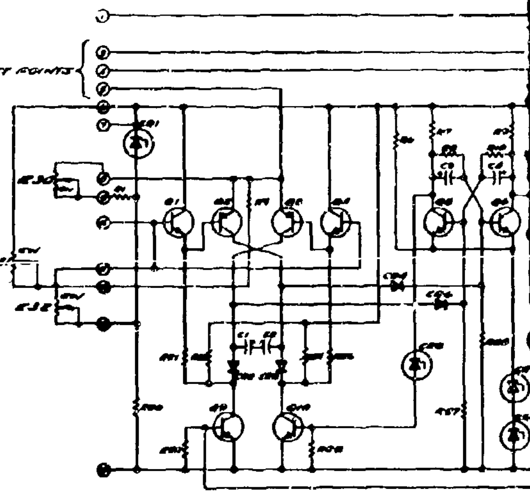
(CONVERTER, SECONDARY)



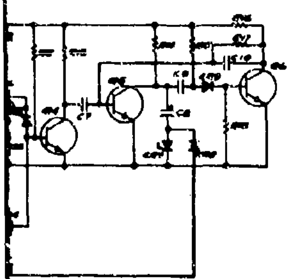
AR8 SCHEMATIC DIAGRAM (SK49
(NSK)

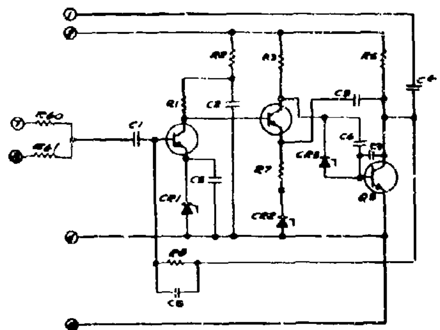
X802949

5 4 3

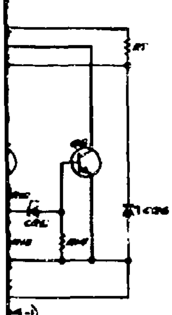
C

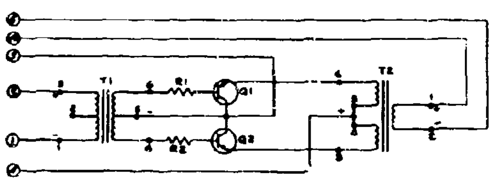
SEE SHEET 1 OF 2 FOR CONTROLLING DRAWING CHANGES



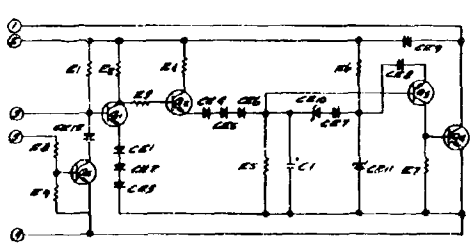


AR9 SCHEMATIC DIAGRAM(814917-1)





G1 SCHEMATIC DIAGRAM(814944-1)
(CHOPPER)



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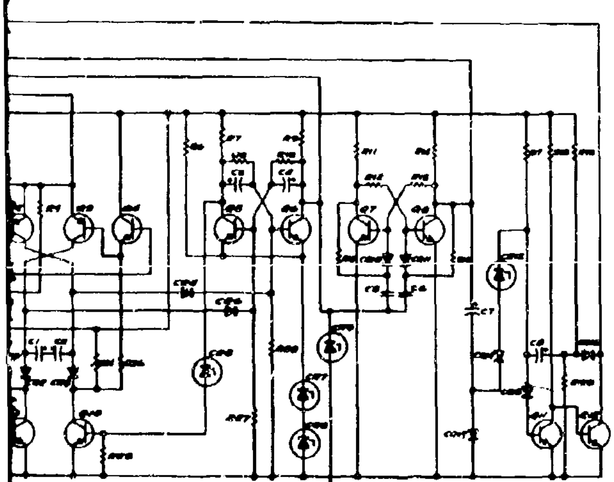
(FLAG TRIP)



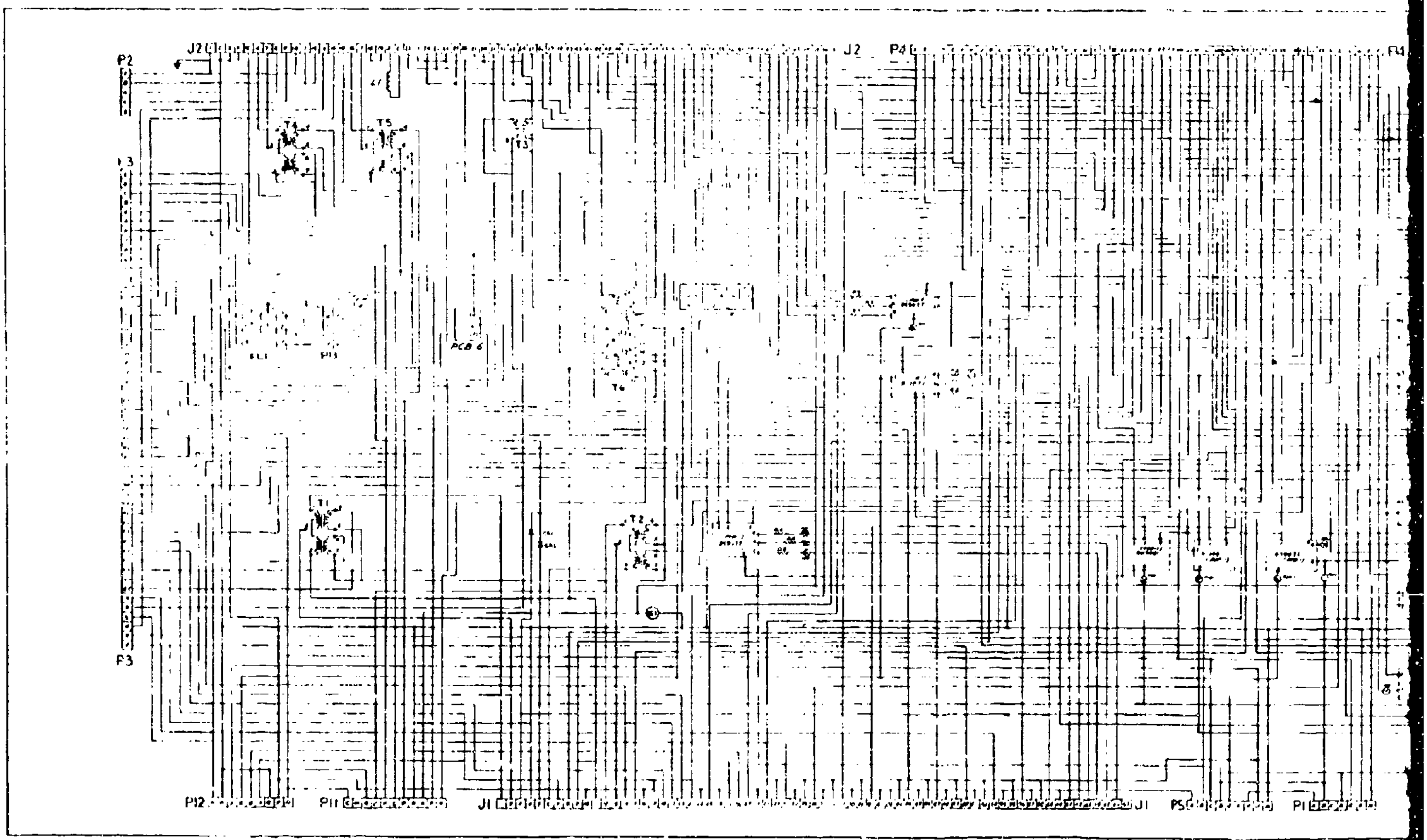
AR8 SCHEMATIC DIAGRAM(814914-1)
(HSA)

X802949 1

WIRING SCHEMATIC, COMPUTER DISPLAY

70210 J X 802949

D



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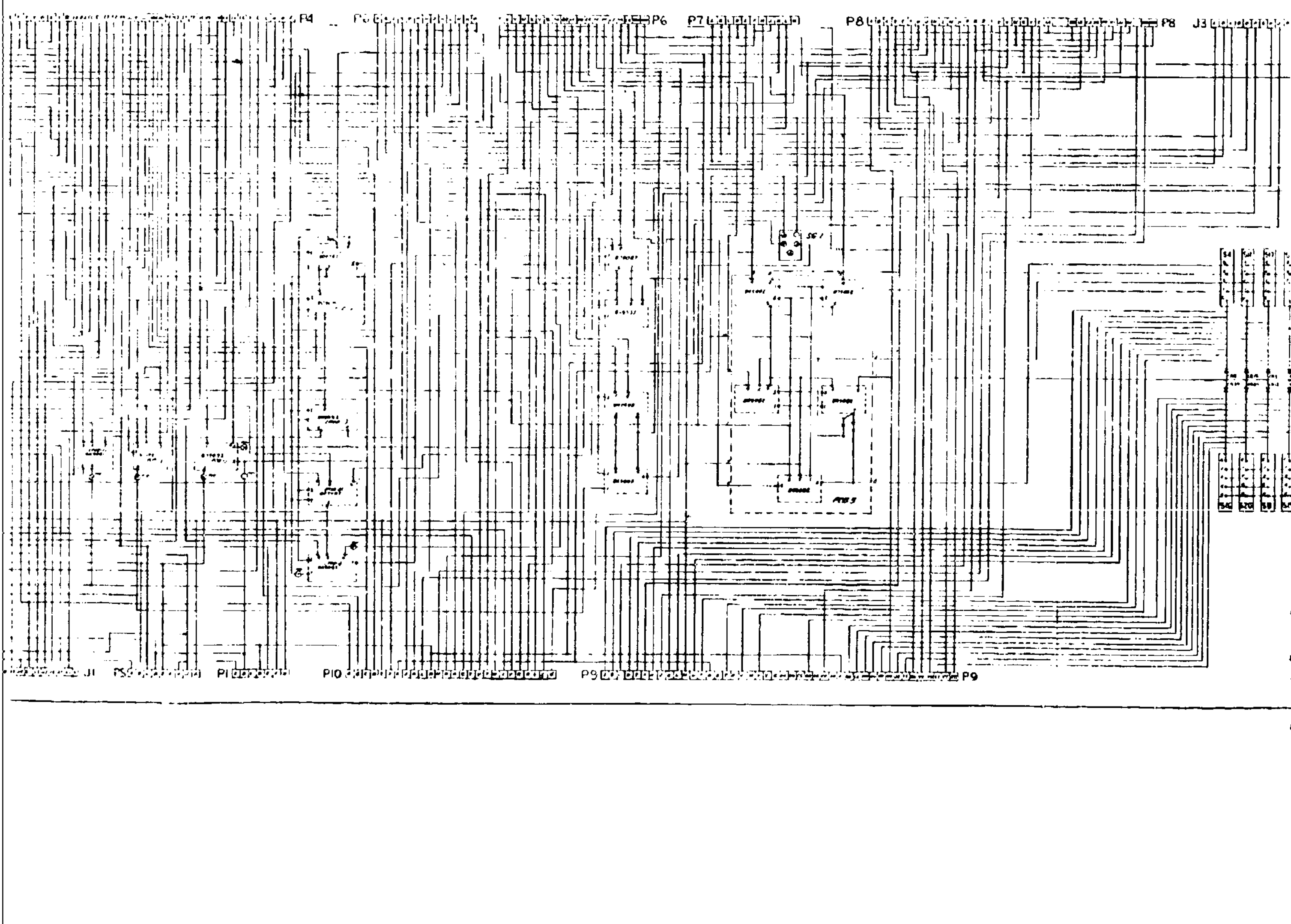
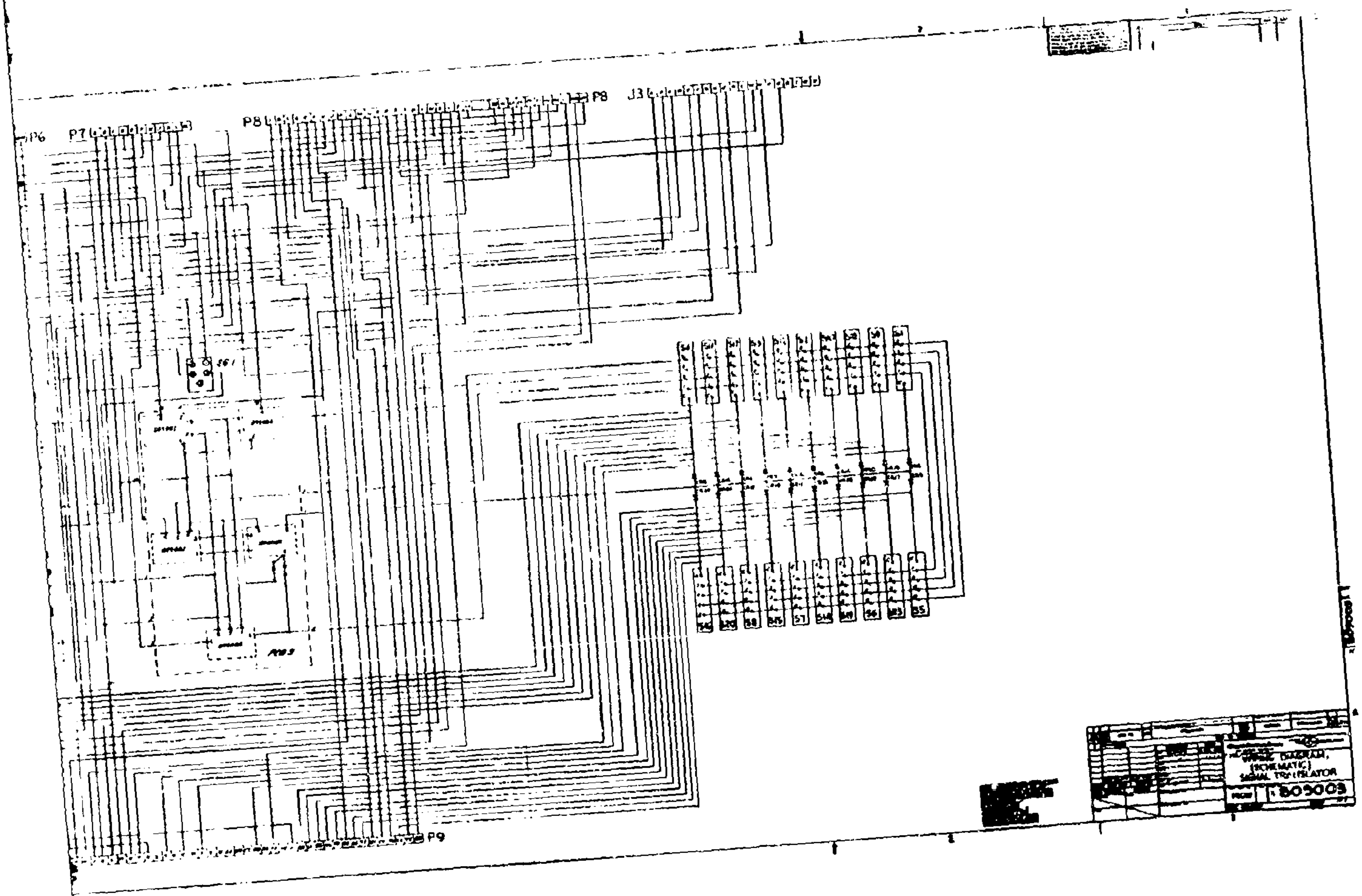
NOT REPRODUCIBLE



B

NOT REPRODUCIBLE

RODUCIBLE



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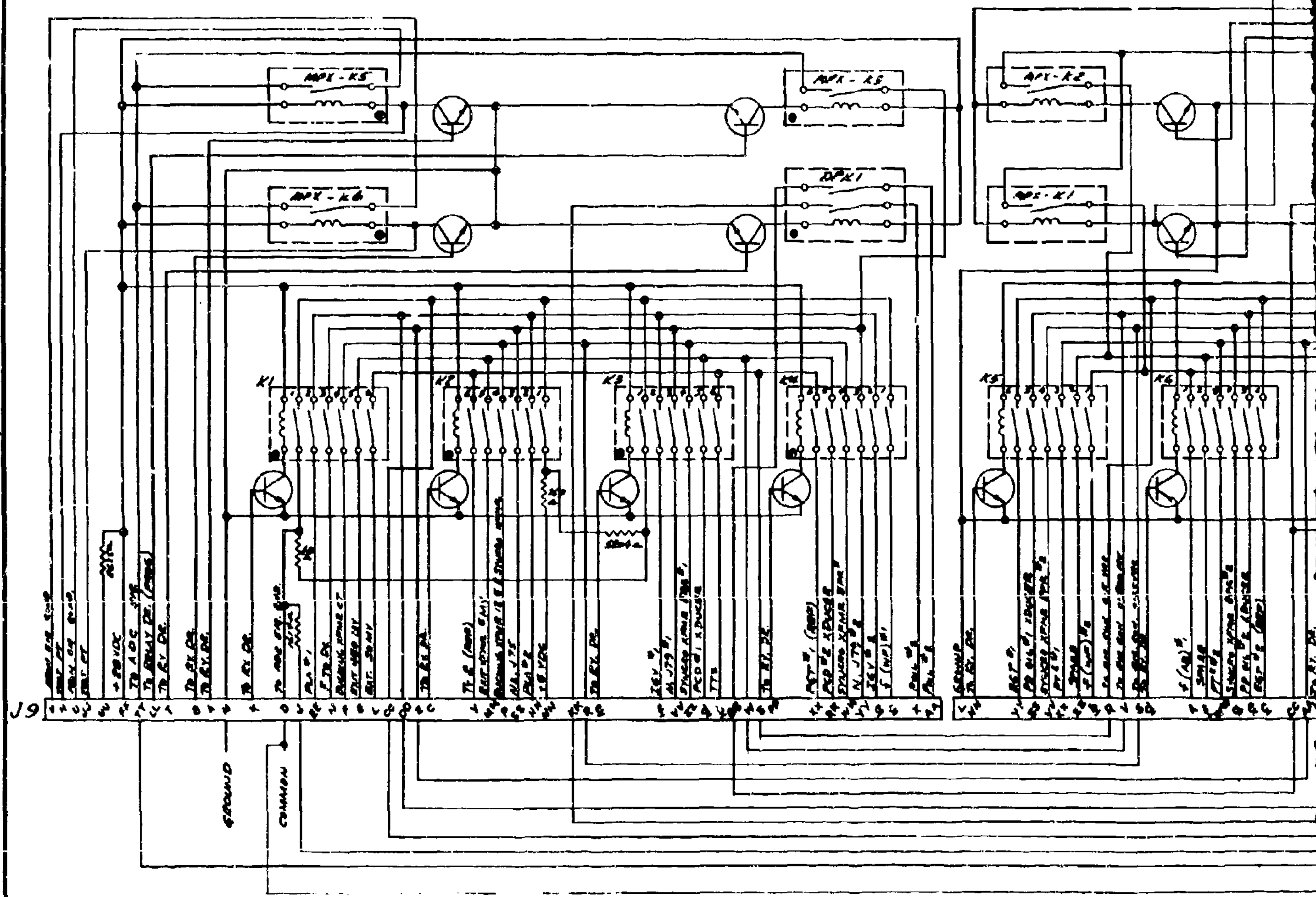

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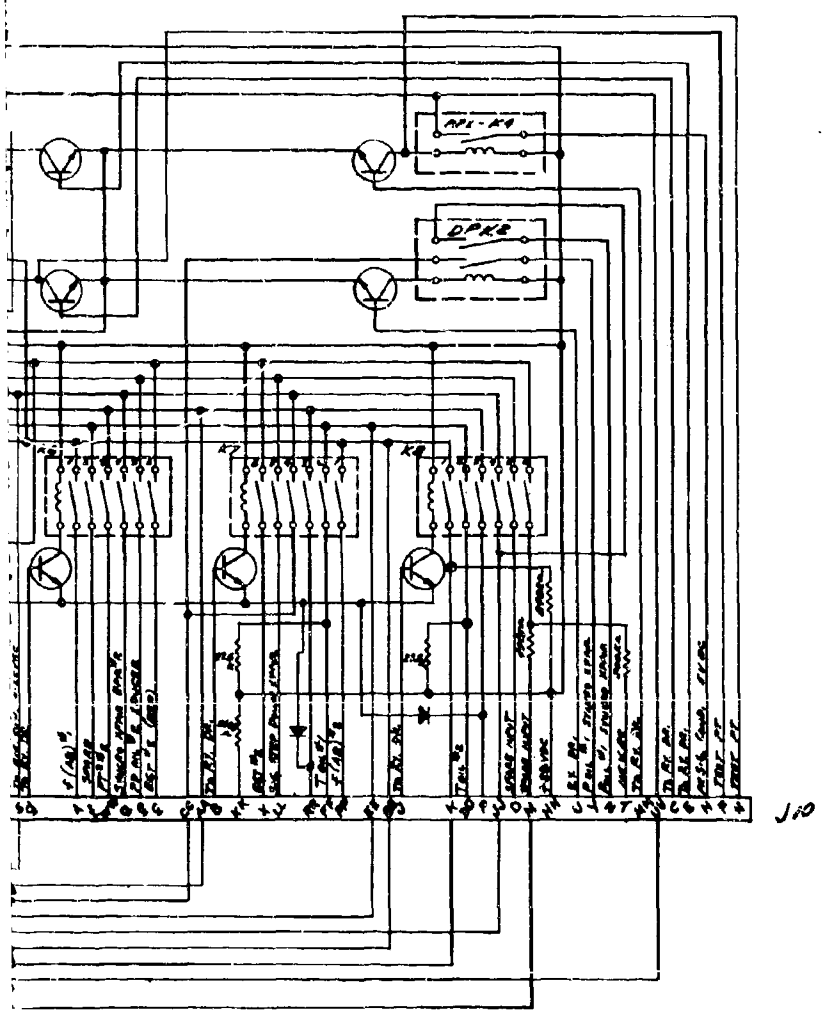
SYM	DESCRIPTION	DATE	APPROVED
REVISIONS			
A	SEE REVISION NOTICE		



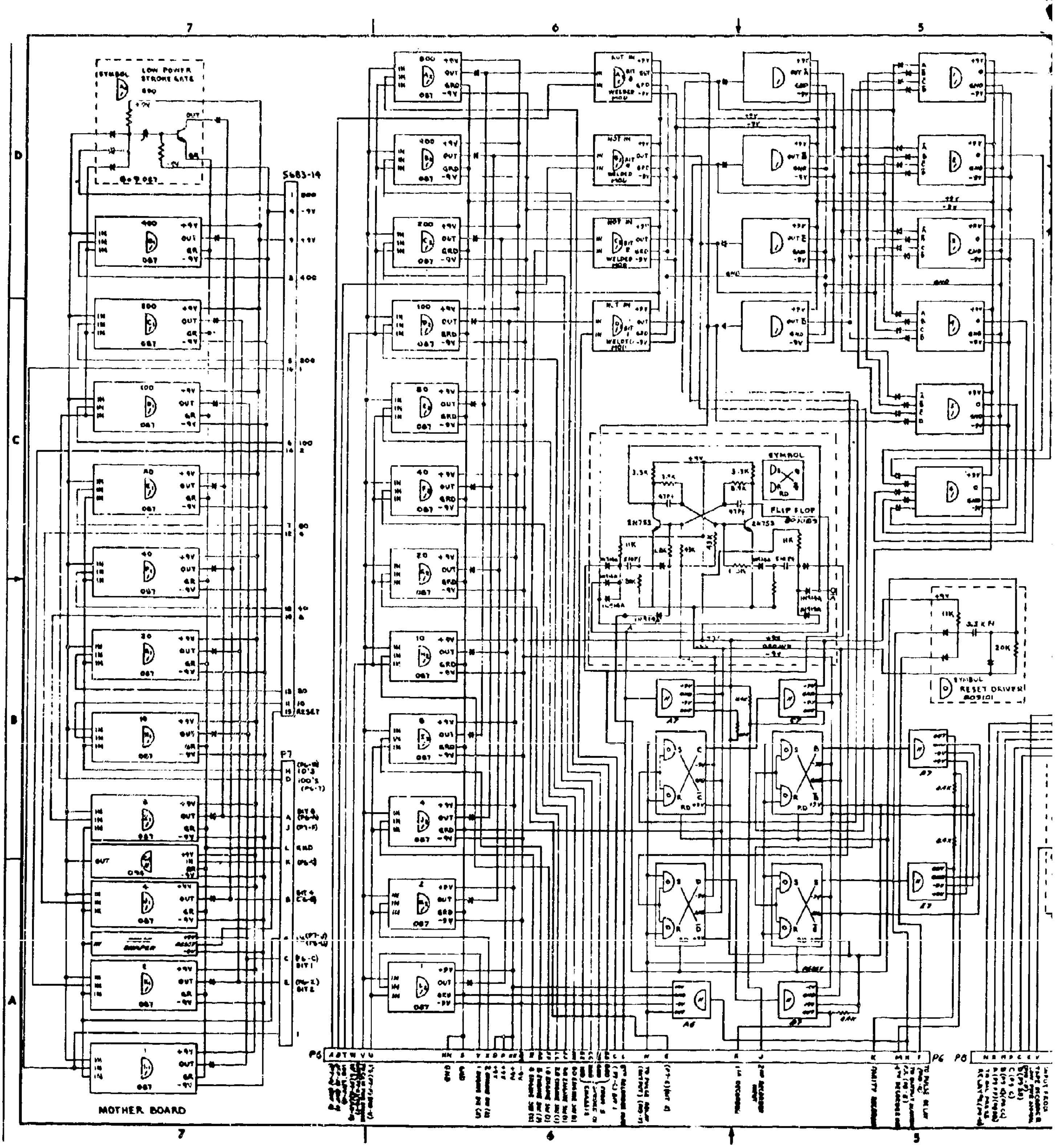
B

QTY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL	SPECIFICATION	UNIT WT
ASSYS				LIST OF MATERIAL				

WIRING DIAGRAM, SCHEMATIC
RELAYS

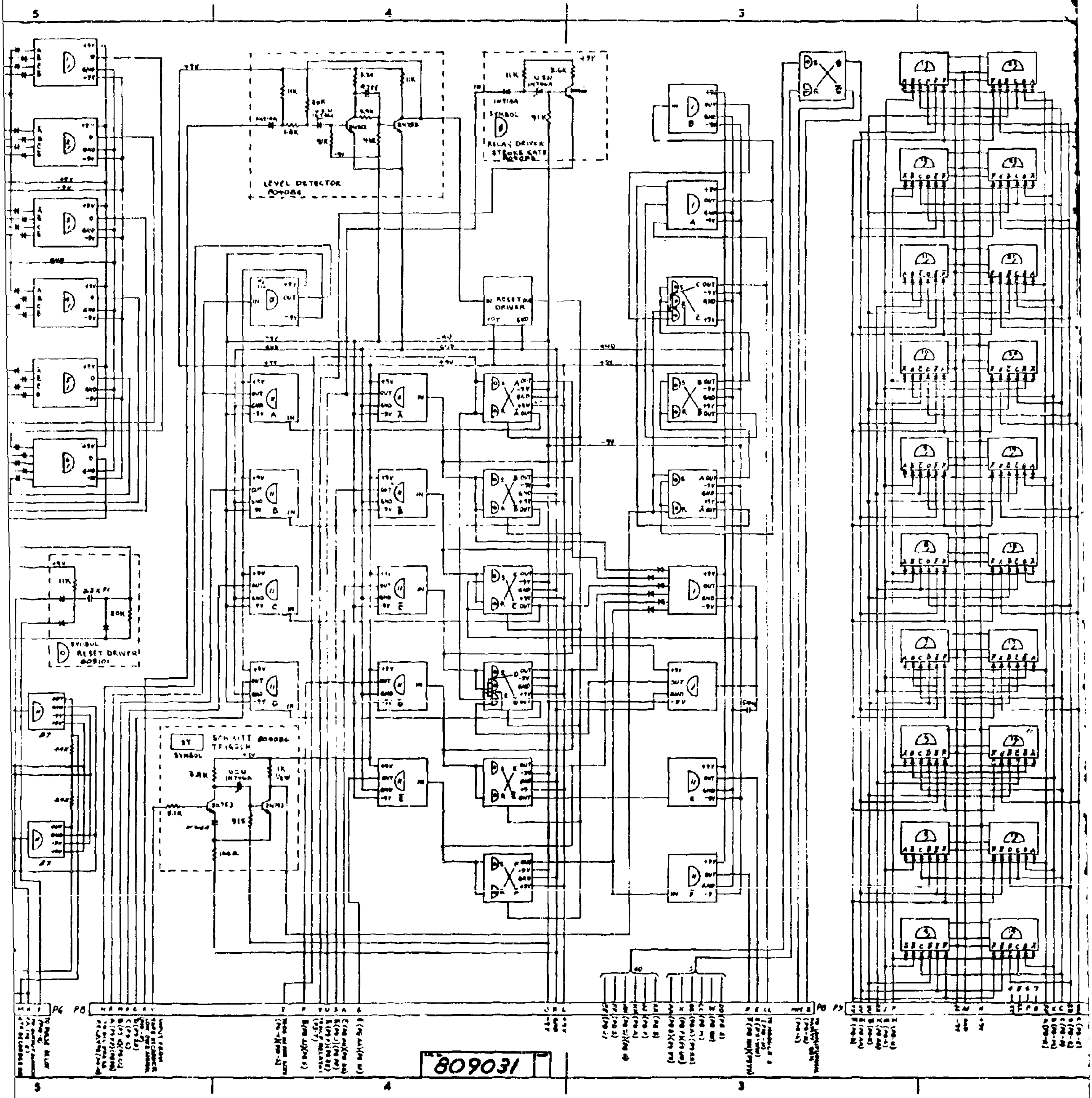
CODE IDENT NO.	SIZE	DWG NO.
70210	D	X809079

SCALE NONE · SHEET 1 OF 1

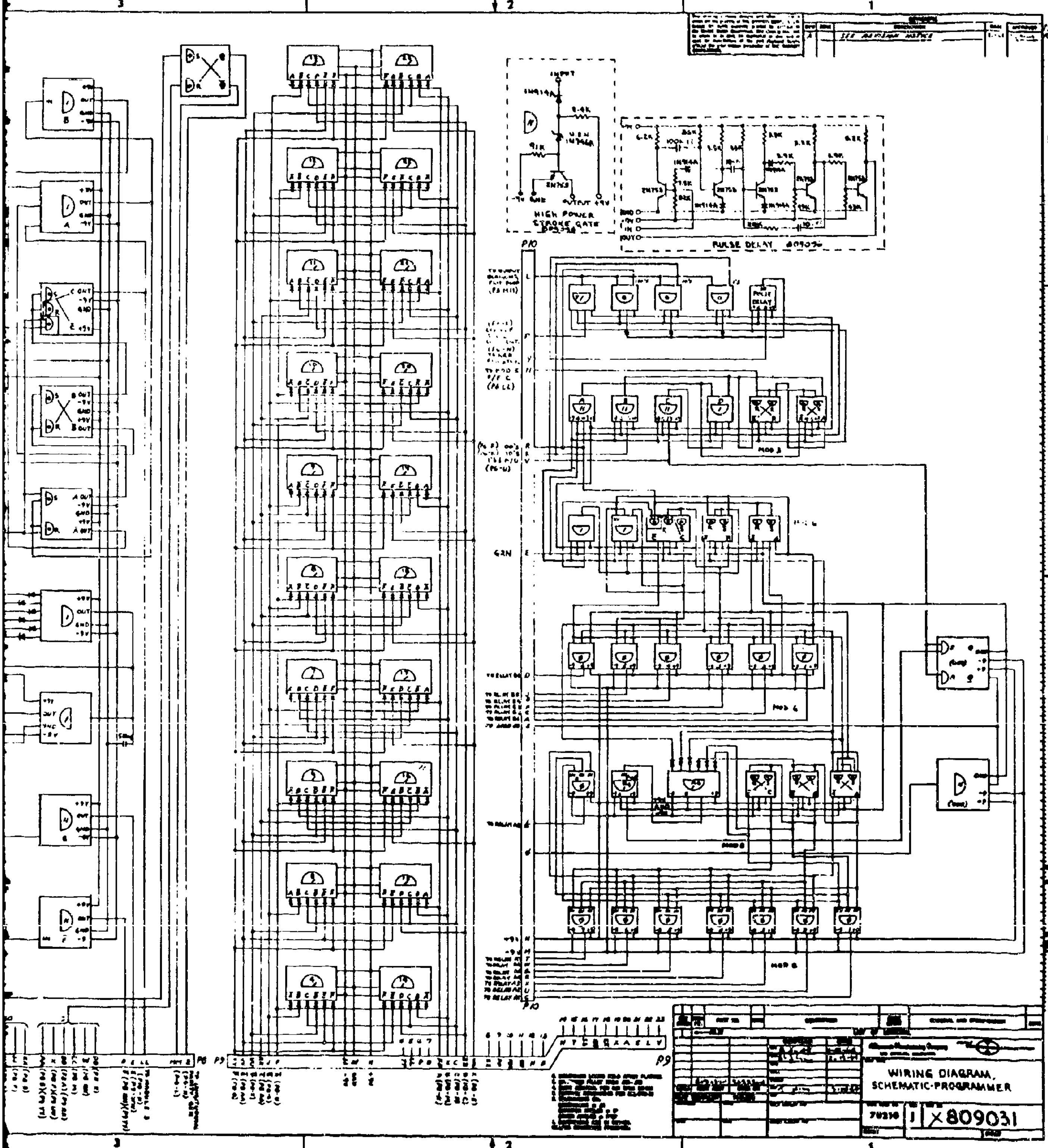


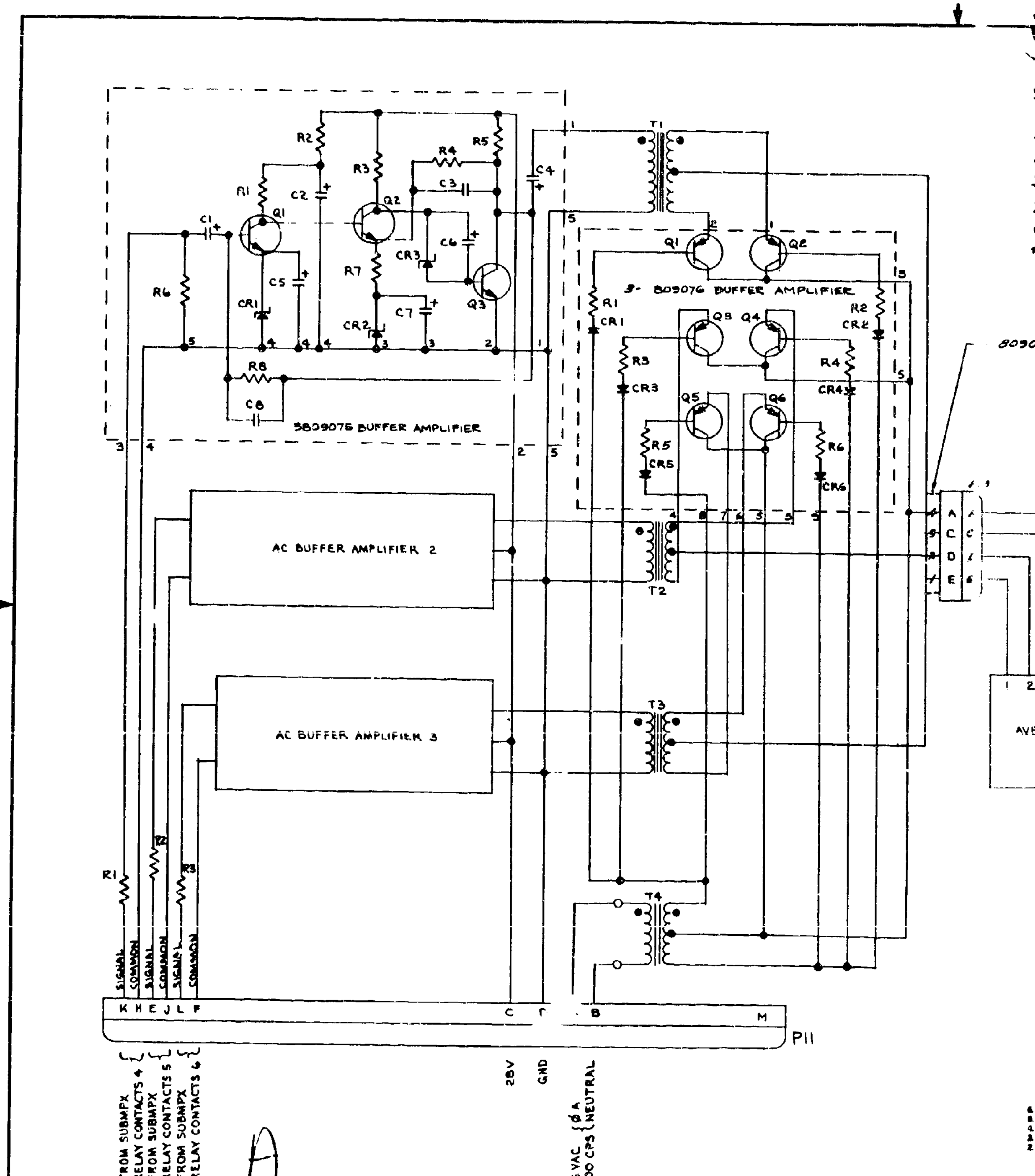
LOW POWER STROBE GATE
MOTHER BOARD
FLIP FLOP
RESET DRIVER
P6
P7
P8

A


LEVEL DETECTOR
RELAY DRIVER
RESET DRIVER
SCHMITT TRIGGER
809031

B

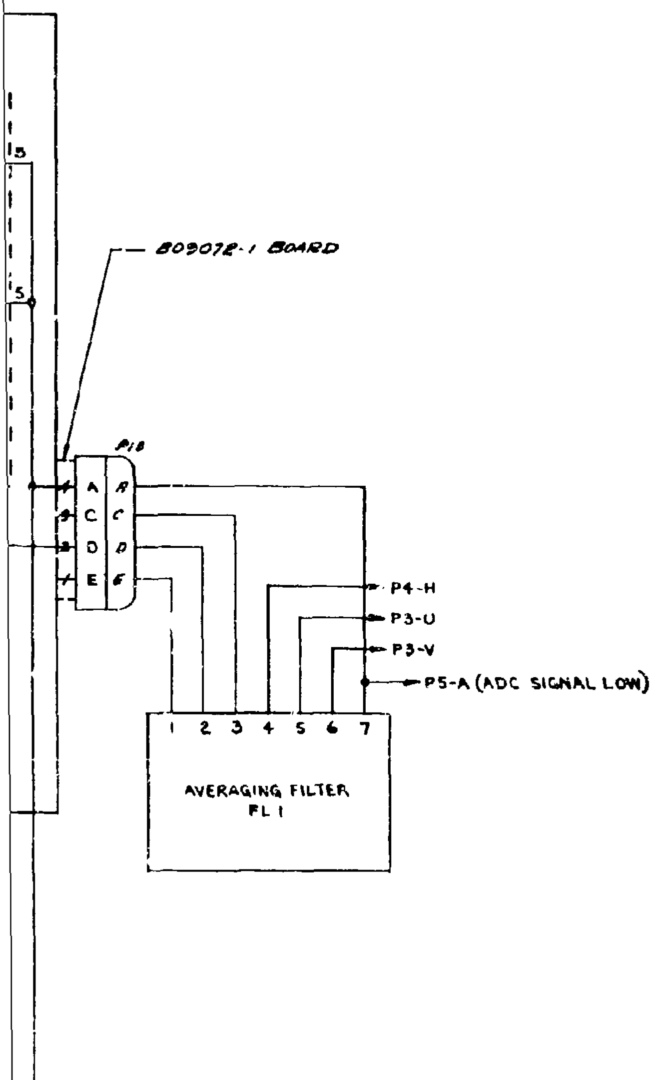

HIGH POWER STROKE GATE
PULSE DELAY 809096
MOD 3
MOD 4
MOD 6
MOD 8
P10
P9
WIRING DIAGRAM, SCHEMATIC-PROGRAMMER
70210
J
X809031



5809075 BUFFER AMPLIFIER
3- 809076 BUFFER AMPLIFIER
AC BUFFER AMPLIFIER 2
AC BUFFER AMPLIFIER 3
T1
T2
T3
T4
P11
SIGNAL
COMMON
SIGNAL
COMMON
SIGNAL
COMMON
K H E J L F
C
B
M
28V
GND
FROM SUBMPX RELAY CONTACTS 4
FROM SUBMPX RELAY CONTACTS 5
FROM SUBMPX RELAY CONTACTS 6
115 VAC 400 CPS
ØA
NEUTRAL
A

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
A	SEE REVISION NOTICE	3-17-64	
B	SEE REVISION NOTICE		

RSE
RSE
RSE



COMPONENT LIST

809075 AMPLIFIER	809076 AMPLIFIER
C1 = CS13AD220K	CR1 = 1N645
C2 = CS13AF010K	CR2 = 1N645
C3 = CT10D-511K GULTON	CR3 = 1N645
C4 = CS13AF220M	CR4 = 1N645
C5 = CS13AD3R3M	CR5 = 1N645
C6 = CS13AF010K	CR6 = 1N645
C7 = CS18AE150M	
C8 = CT10D-100K GULTON	Q1 = 2N2336
	Q2 = 2N2336
CR1 = 1N713A	Q3 = 2N2336
CR2 = 1N717A	Q4 = 2N2336
CR3 = 1N720A	
	R1 = RL07AD223J
Q1 = 2N910	R2 = RL07AD223J
Q2 = 2N910	R3 = RL07AD223J
Q3 = 2N910	R4 = RL07AD223J
	R5 = RL07AD223J
R1 = RL07AD104J	R6 = RL07AD223J
R2 = RL07AD393J	
R3 = RL07AD623J	R1 = RN65E1004F MIL-R-10509/2
R4 = RL07AD513J	R2 = RN65E2002F MIL-R-10509/2
R5 = RL07AD752J	R3 = RN65E2003F MIL-R-10509/2
~~R6 = RL07AD104J~~	
R7 = RL07AD510J	J1 = MM11-22PGDS (CONTINENTAL)
R8 = RN65E2003F	
	T1 = 15030 HADLEY
FL1 = LP4318 (RYTRON)	T2 = 15030 HADLEY
	T3 = 15030 HADLEY
	T4 = 15031 HADLEY

B

QTY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION
		← ASSY		LIST OF MATERIAL		

6. DIMENSION LIMITS HOLD AFTER FLATING
5. MACHINED FILLET RADII .015
4. BURR CONTROL PER AIR SPEC
3. SURFACE ROUGHNESS PER MIL-STD-10
2. TOLERANCES ON:
   DECIMALS ± .03
   CHAMFER ANGLES ± 5°
   OTHER ANGLES ± 0°30'
1. DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED

SIGNATURES	DATES
DR	12-21-63
CHK	
ENG	
APP	

AiResearch Manufacturing Company
LOS ANGELES, CALIFORNIA

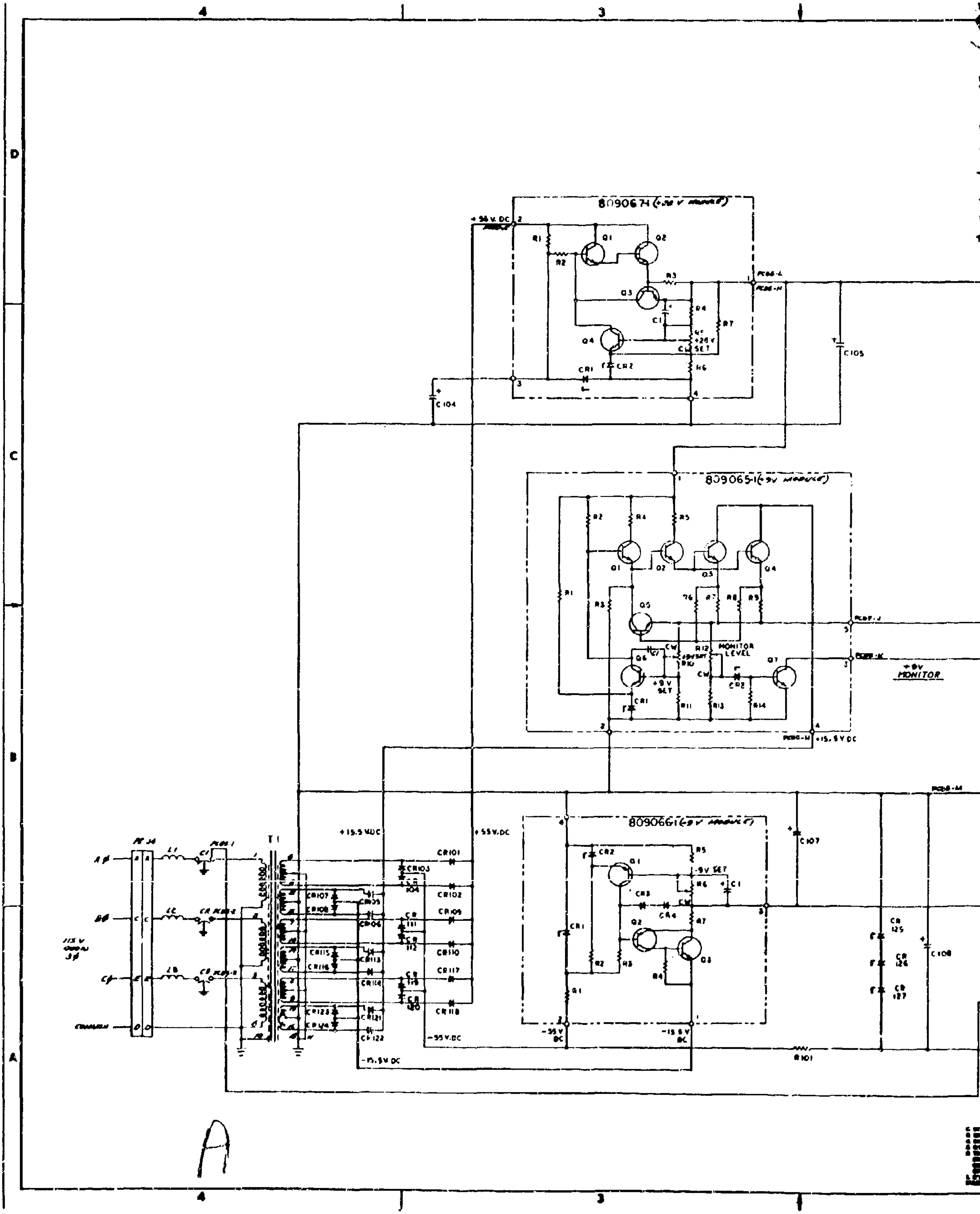
THE GARRETT CORPORATION

WIRING DIAGRAM, SIGNAL CONDITIONERS

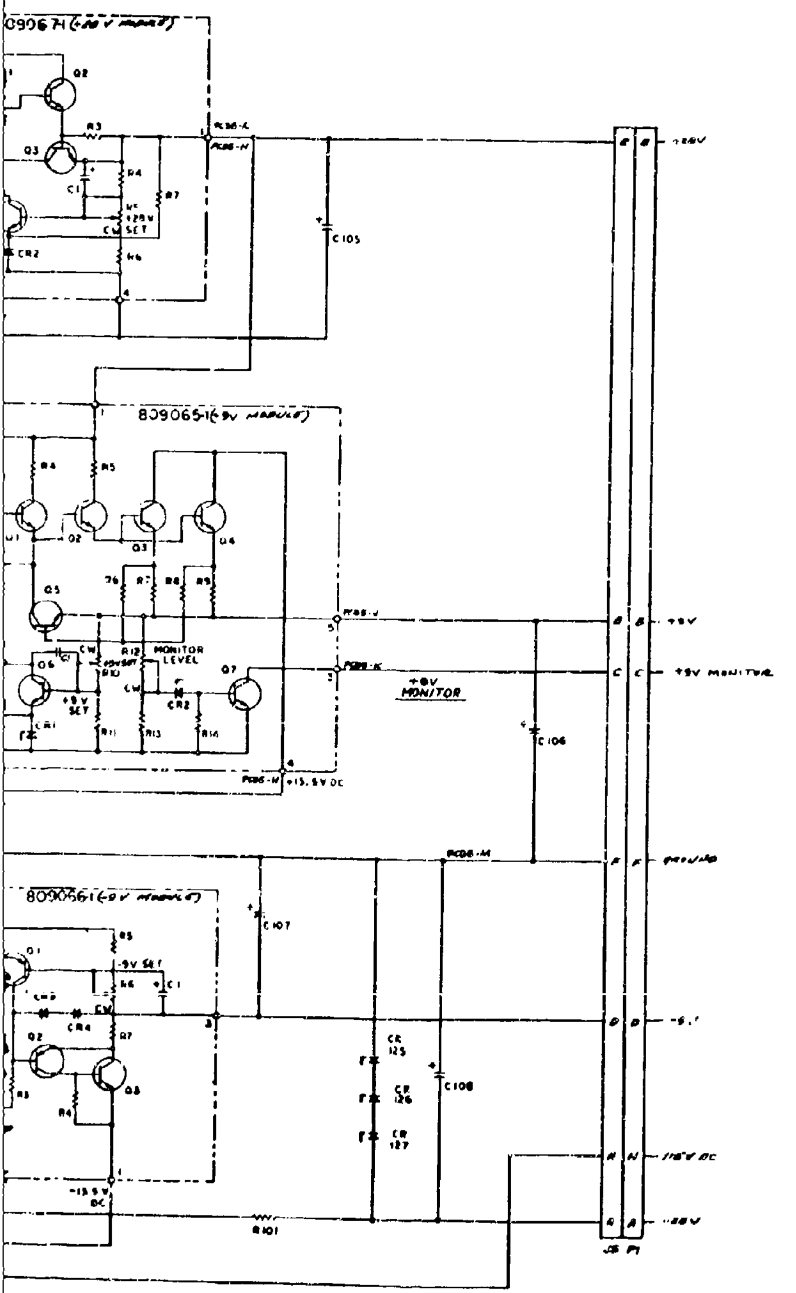
CODE IDENT NO.	SIZE	DWG NO.
70210	D	X809071

SCALE — SHEET 1 OF 1

X809071



809067-1
809065-1
809066-1
+55 V DC
+15.5 VDC
+55 V.DC
-55 V.DC
-15.5 V DC
+15.5 V DC
+9 V SET
-9 V SET
+28 V SET
MONITOR LEVEL
+9V MONITOR
-55 V DC
-15.5 V DC
T1
C104
C105
C107
C108
R101
CR101
CR102
CR103
CR109
CR110
CR117
CR118



SEE REVISION NOTICE

809067 - +28 V. CIRCUITS

Q1 - 2N910
Q2 - 2N2593
Q3 - 2N731
Q4 - 2N2222

CR1 - 1036 B
CR2 - 1N3514

C1 - .15 μf

R1 - 2.5 K ±3% 1 W RS-1A
R2 - 3.9 K ±5% 1/4 W
R3 - 1.5 Ω ±3% 1 W RS-1A
R4 - 4.7 K ±1% 1 W RS-1A
R5 - 2.0 K POT
R6 - 1.3 K ±1% 1/4 W RS-1/4
R7 - 6.2 K ±5% 1/2 W

PA 56947 HEAT SINK

809065 - +9 V. CIRCUITS

Q1 - 2N2222
Q2 - 2N2222
Q3 - 2N2983
Q4 - 2N2983
Q5 - 2N2222
Q6 - 2N731
Q7 - 2N914

CR1 - 1N3514
CR2 - 1N3514

C1 - .0015 μf 100V CTX02 162K GULTON

R1 - 2.2 K ±3% 1 W RS-1A
R2 - 4.3 K ±5% 1/2 W
R3 - 10 K ±5% 1/4 W
R4 - 4.7 K ±5% 1/2 W
R5 - 200 Ω ±5% 2 W
R6 - 100 Ω ±5% 1/4 W
R7 - 0.75 Ω ±3% 1 W RS-1A
R8 - 100 Ω ±5% 1/4 W
R9 - 0.75 Ω ±3% 1 W RS-1A
R10 - 500 Ω POT
R11 - 1.1 K ±1% 1/4 W RS-1/4
R12 500 Ω POT
R13 1.5 K ±5% 1/4 W
R14 10 K ±5% 1/4 W

TK BP-019-078-1 DISSIPATOR
TK BP-032-037-1 DISSIPATOR
PA 56946 MOUNTING PLATE

809066 - -9 V CIRCUITS

Q1 - 2N2907
Q2 - 2N2907
Q3 - 2N2983

CR1 - 1010 B DIODES INC.
CR2 - 1N3514
CR3 - 1N3758
CR4 - 1N3758

C1 - 0.15 μf

R1 - 2K ±3% 1 W RS-1A
R2 - 2.2K ±3% 1 W RS-1A
R3 - 4.7K ±3% 1 W RS-1A
R4 - 1 K ±5% 1/4 W
R5 - 1.1 K ±1% 1/4 W RS-1/4
R6 - 500 Ω POT
R7 - 1.8 Ω ±3% 1 W RS-1A

INTER-CONNECTING CIRCUITRY

T1 - TRANSFORMER, POWER

CR101 - 1N3758
CR102
CR103
CR104
CR105
CR106
CR107
CR108
CR109
CR110
CR111
CR112
CR113
CR114
CR115
CR116
CR117
CR118
CR119
CR120
CR121
CR122
CR123
CR124 - 1N3758
CR125 - 10 B/B, 9.1V ±5%
CR126 - 10 B/B, 9.1V ±5%
CR127 - 10 B/B, 9.1V ±5%

C1 - .047 μf 600 VDC
C2 - .047 μf 600 VDC
C3 - .047 μf 600 VDC
C101 - .01 μf 600 VDC
C102 - .01 μf 600 VDC
C103 - .01 μf 600 VDC
C104 - 22 μf 70 VDC
C105 - 33 μf 50 VDC
C106 - 180 μf
C107 - 100 μf
C108 - 33 μf 50 VDC

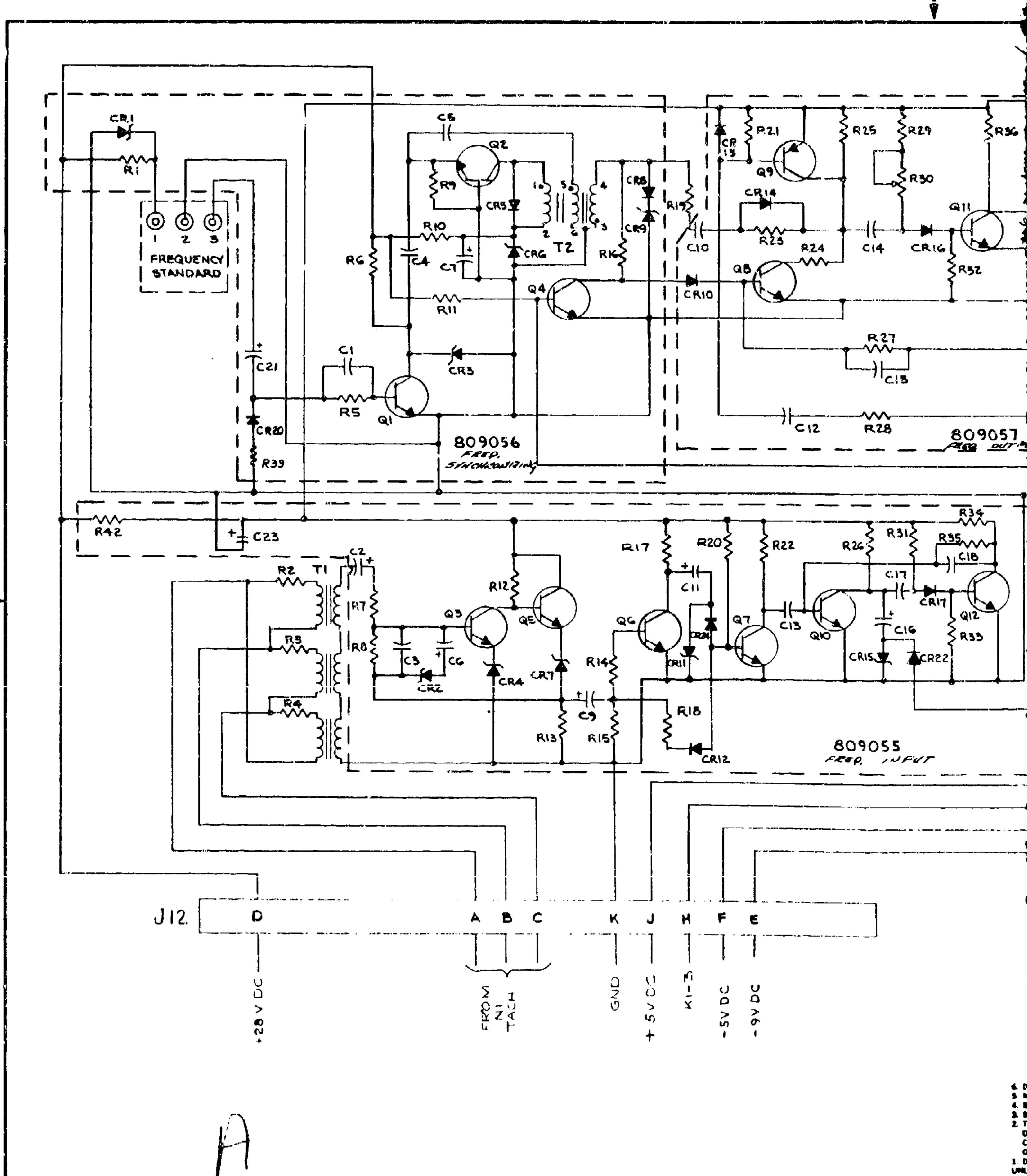
R101 - 820 Ω 3 W

L1 - 600 mH
L2 - 600 mH
L3 - 600 mH

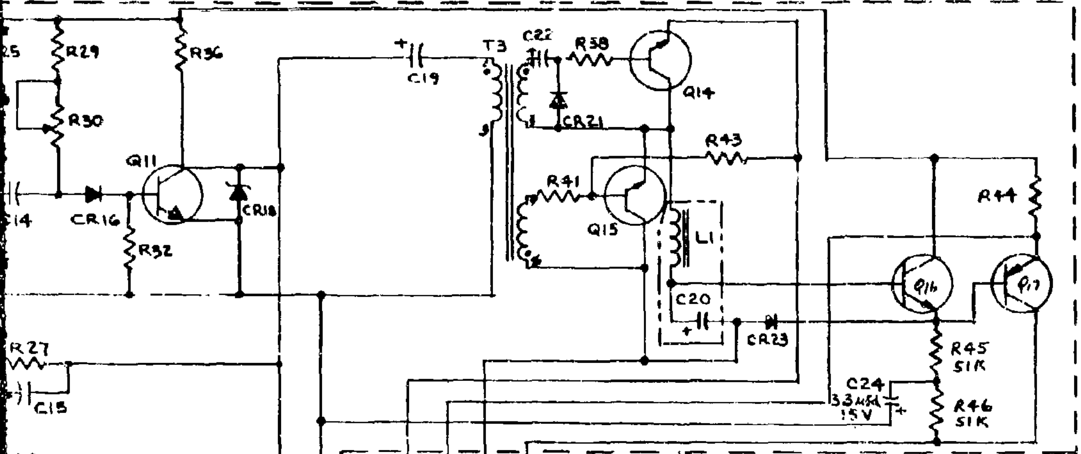
B

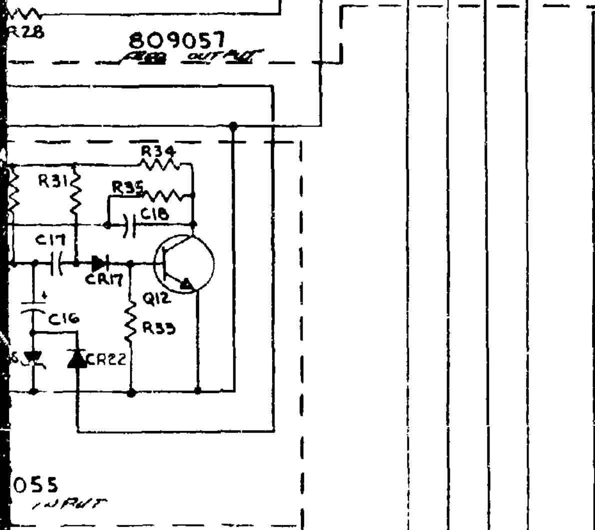
WIRING DIAGRAM - SCHEMATIC
POWER SUPPLY

78210 E X809061



FREQUENCY STANDARD
1 2 3
CR1
R1
C5
Q2
R9
CR5
T2
CR8
CR9
R19
R10
C4
C7
CR6
R6
RK
C10
R11
Q4
CR10
C1
CR3
R5
Q1
C21
CR20
R39
809056
FREQ. SYNCHRONIZING
CR 13
R21
Q9
R25
R29
R30
R36
CR14
R23
R24
C14
CR16
Q11
R32
Q8
R27
C15
C12
R28
809057
R42
C23
R2
T1
C2
R7
R8
R3
R4
R12
Q3
Q5
C3
C6
CR2
CR4
CR7
R13
C9
R14
R15
R17
C11
Q6
CR11
R20
CR21
Q7
R22
R18
CR12
R26
R31
R34
R35
C18
C17
C13
Q10
CR17
Q12
C16
CR15
CR22
R33
809055
FREQ. INPUT
J12
D
A B C
K
J
H
F
E
+28 V DC
FROM N1 TACH
GND
+5 V DC
K1-3
-5V DC
-9V DC





REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED

RGE

COMPONENT LIST

C1 = 470 pfd CT10D-471M
C2 = 22 μfd 15V 150D226X0015B2
C3 = .001 μfd CT10D-102M
C4 = .0022 μfd CT10
C5 = .0022 Mfd CT10
C6 = 1 μfd 35V 150D105X0015A2
C7 = 1 μfd 35V 150D105X0020A2
~~C8 = 2.2 μfd 15V 150D225X0015A2~~
C9 = 22 μfd 15V 150D226X0015B2
C10 = 470 pfd CT10D-471 M
C11 = .068 Mfd 150D 683X9035B2
C12 = .0047 μfd CT10
C13 = .0047 μfd 35VDC CT10
C14 = 0.10 μfd 200V BALCO TYPE PKBM
C15 = 100 pfd CT10D-101M
C16 = 1 μfd 35V 150D105X0035A2
C17 = .01 μfd CT10D
C18 = 100 pfd CT10D-101M
C19 = 22 μfd 15V 150D105X0015A2
C20 = 10 μfd 70V 150D106C2070F2
C21 = 1 μfd 35VDC
C22 = 6.8 μfd 6VDC CS13AB6R8K
C23 = 6.8 μfd 35VDC CS13AF6R8K
C24 = 3.3 μfd 15V
CR1 = 1N759A
CR2 = 1N752A
CR3 = 1N752A
CR4 = 1N752A
CR5 = 1N645
CR6 = 1N758A
CR7 = 1N752A
CR8 = 1N914A
CR9 = 1N749A
CR10 = 1N914A
CR11 = 1N749A
CR12 = 1N457
CR13 = 1N457
CR14 = 1N914A
CR15 = 1N749A

CR16 = 1N457
CR17 = 1N457
CR18 = 1N758A
~~CR19 = 1N752A~~
CR20 = 1N457
CR21 = 1N457
CR22 = 1N457
CR23 =
CR24 = 1N457
L1 = 14758

Q1 = 2N2221
Q2 = 2N2221
Q3 = 2N2222
Q4 = 2N2221
Q5 = 2N2221
Q6 = 2N2221
Q7 = 2N2221
Q8 = 2N2221
Q9 = 2N2907
Q10 = 2N2221
Q11 = 2N2221
Q12 = 2N2221
~~Q13 = 2N2221~~
Q14 = 2N2432
Q15 = 2N2432
Q16 = 2N2221
Q17 = 2N2907
R1 = MS35043-94 (2 K)
R2 = 621-002-9171 (2000Ω) 3W
R3 = 621-002-9171
R4 = 621-002-9171
R5 = RL07AD103J (10K)
R6 = MS35043-104 (5.1K)
R7 = RL07AD103J (10K)
R8 = RL07AD104J (100K)

R9 = RL07AD102J (1K)
R10 = MS35043-111 (10K)
R11 = RL07AD513J (51K)
R12 = RL07AD203J (20K)
R13 = MS35043-98 (3K)
R14 = RL07AD822J (8.2 K)
R15 = RL07AD302J (3K)
R16 = RL07AD202J (2K)
R17 = MS35043-111 (10K)
R18 = RL07AD102J (1K)
R19 = MS35043 -
R20 = RL07AD513J (51K)
R21 = RL07AD204J (200K)
R22 = MS35043-111 (10K)
R23 = MS35043-122 (30K)
R24 = RN60E1001F (1K)
R25 = RN60E1002F (10K)
R26 = MS35043-98 (3K)
R27 = RL07AD513J (51 K)
R28 = RL07AD113J (11K)
R29 = RN60E2322F ( )
R30 = 50-2-1-502 (5K)
R31 = RL07AD513J (51K)
R32 = RL07AD204J (200K)
R33 = RL07AD104J (100K)
R34 = MS35043-104 (5.1K)
R35 = RL07AD513J (51K)
R36 = MS35043-99 (2.4K)
~~R37 = MS35043-104 (5.1K)~~
R38 = RL07AD392J (3.9K)
R39 = RL07AD103J (10K)
R40 = RL07AD512J (5.1K)
R41 = RL07AD392J (3.9K)
R42 = MS35043-70 (200Ω)
R43 = RL07AD203J (20K)
R44 = RL07AD513J (51K)
T1 = 14735
T2 = PIP-3 (UTC)
T3 = DIT 278 (UTC)

QTY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION
	←ASSY			LIST OF MATERIAL		

6. DIMENSION LIMITS HELD AFTER PLATING.
5. MACHINED FILLET RADII .005-.015
4. BURR CONTROL PER AIR SPEC BC-652
3. SURFACE ROUGHNESS PER MIL-STD-10
2. TOLERANCES ON:
DIMENSIONS ± .01
CHAMFER ANGLES ± 5°
OTHER ANGLES ± 0°30'
1. DIMENSIONS ARE IN INCHES.
UNLESS OTHERWISE SPECIFIED.

809050	809101	
REQD	NEXT ASSY	USED ON
HEAT TREATMENT	PROCESS	

SIGNATURES — DATES
D. Sauln — 12-7-64
[illegible] — 7-21-64

AiResearch Manufacturing Company — THE GARRETT CORPORATION
LOS ANGELES CALIFORNIA

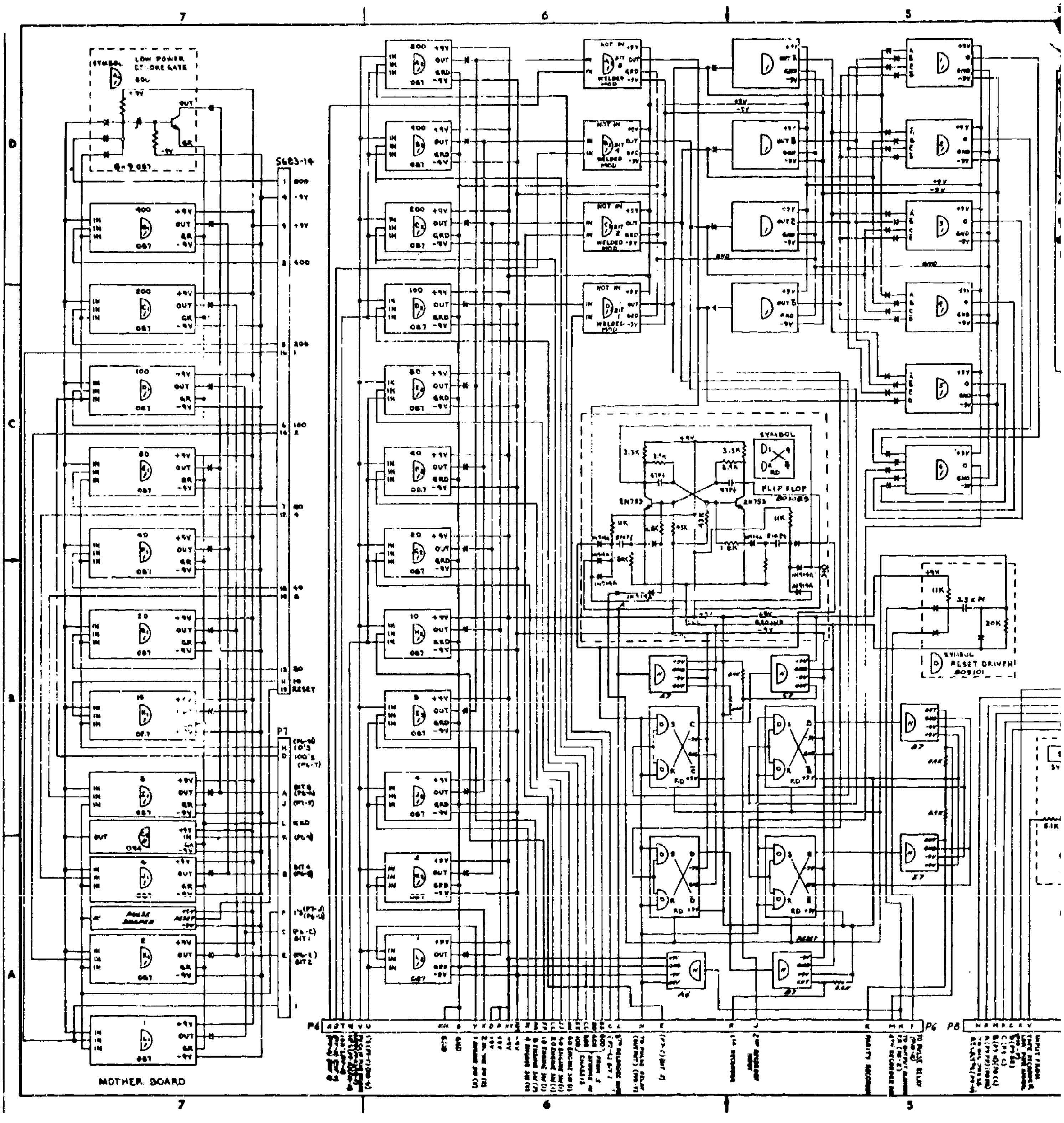
WIRING DIAGRAM SCHEMATIC
FREQUENCY TO DIRECT CURRENT

CODE IDENT NO. 70210 — SIZE D — DWG NO. X 809051

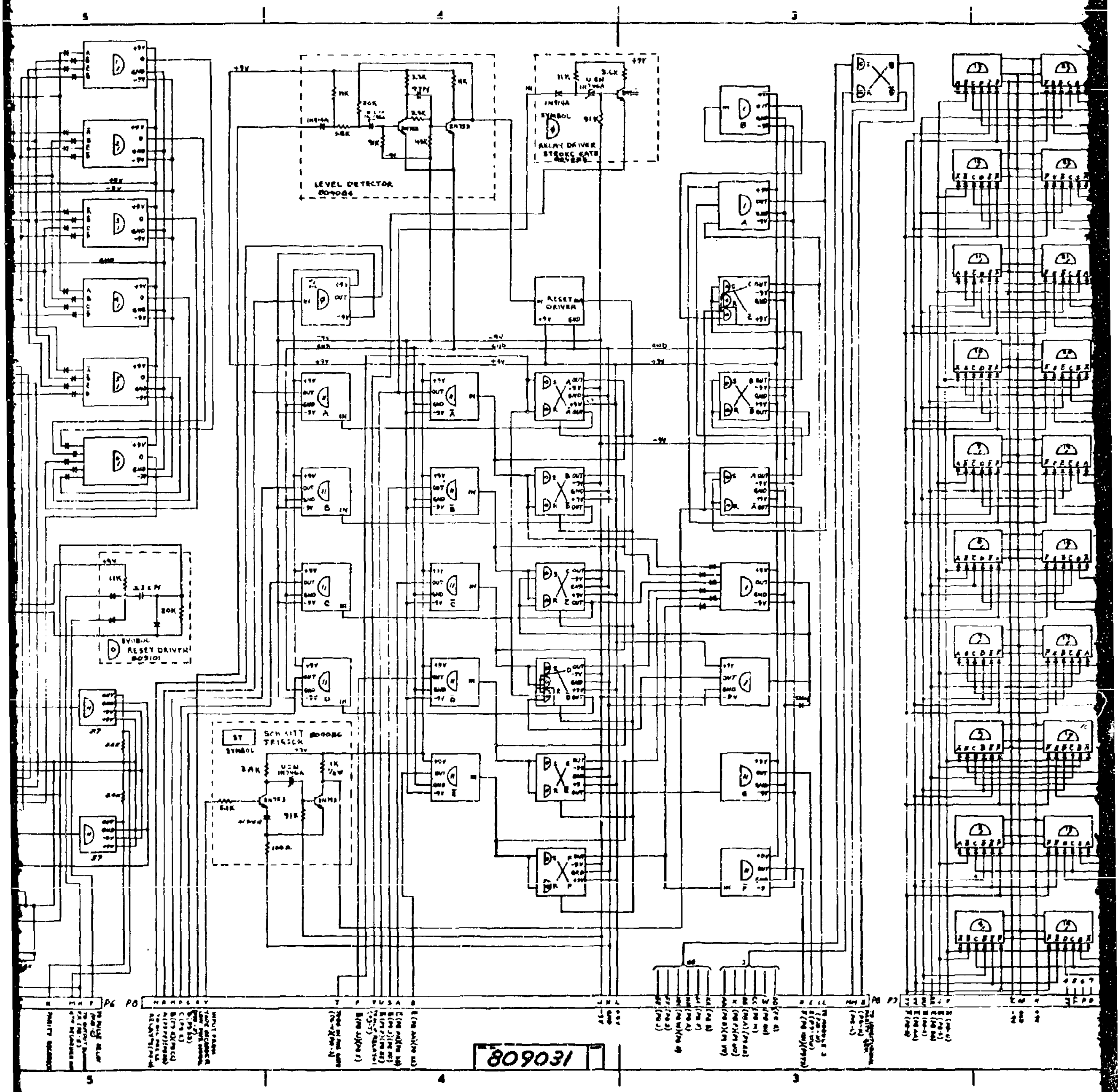
B

SCALE — SHEET

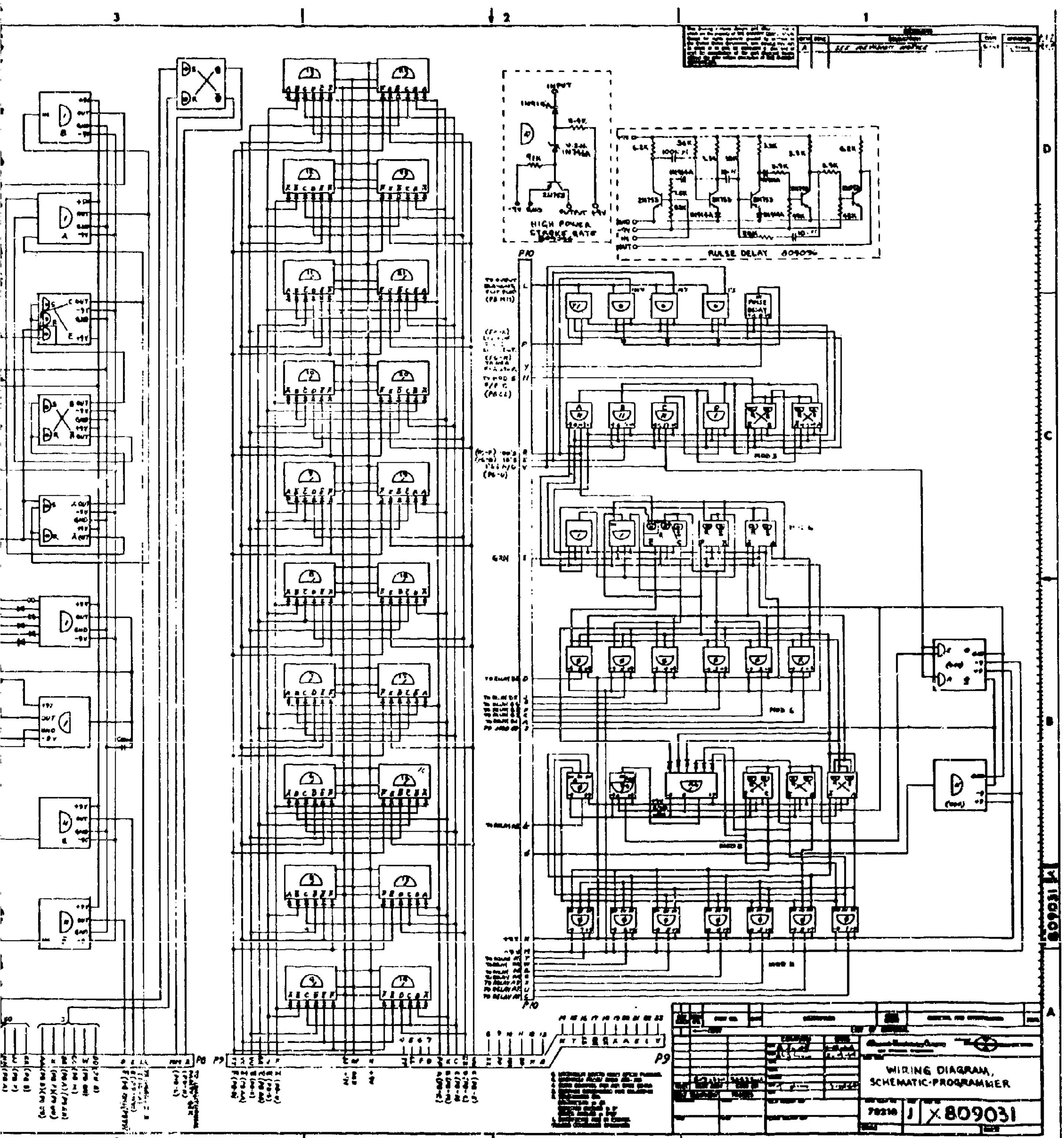
X 809051


7
6
5
D
C
B
A
S683-14
RESET
P7
P6
P8
SYMBOL
FLIP FLOP
RESET DRIVER
MOTHER BOARD

A


LEVEL DETECTOR
809084
RESET DRIVER
SCHMITT TRIGGER 809086
SYMBOL
RESET DRIVER
809101
809031

B



HIGH POWER STROBE GATE
PULSE DELAY 809096
P10
P9
MOD 5
MOD 6
MOD 8
WIRING DIAGRAM, SCHEMATIC-PROGRAMMER
78210
J
X809031

C

Schematic 898-308 for the Data Recorder System EMR-2, P/N 538956, is available from Elgin Research and Development, Division of Elgin National Watch Company, Elgin, Illinois, Drawing 898-308 Project 20898.

APPENDIX II

CIRCUIT SCHEMATICS FOR F-4C ENGINE ANALYZER SYSTEM

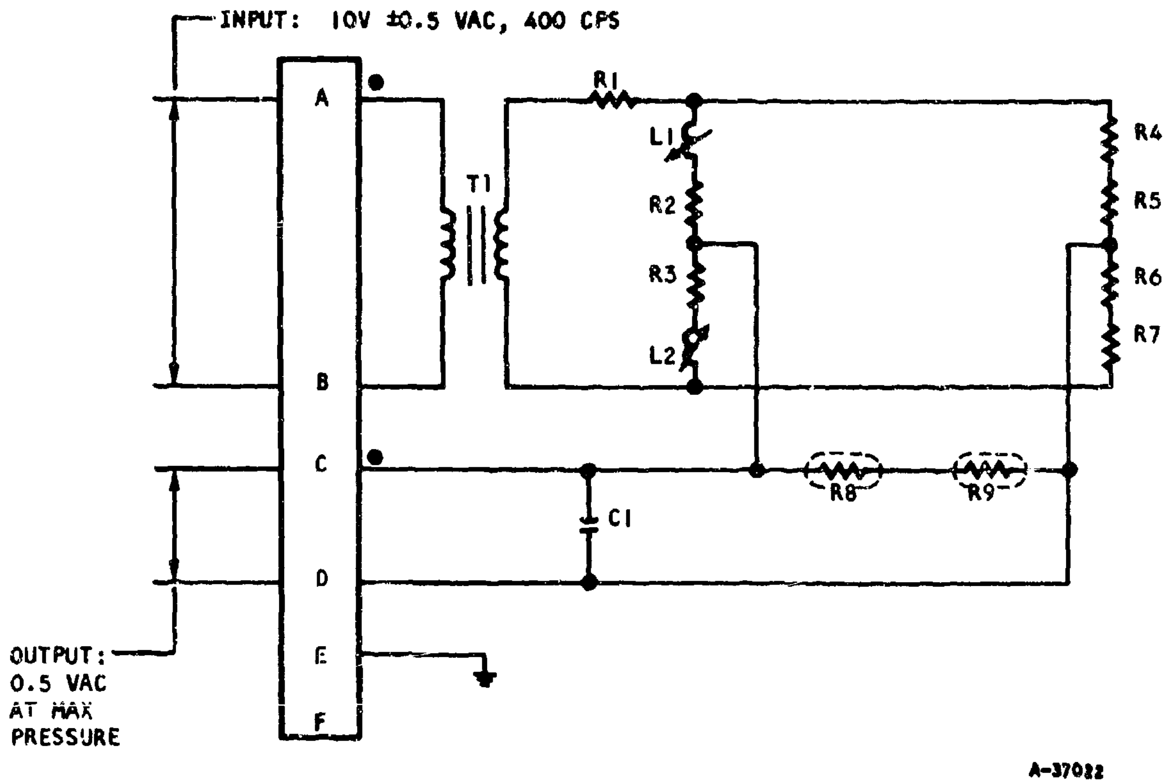


Figure 30. Compressor Discharge Pressure Transducer (P/N 538947-1) Circuit Schematic

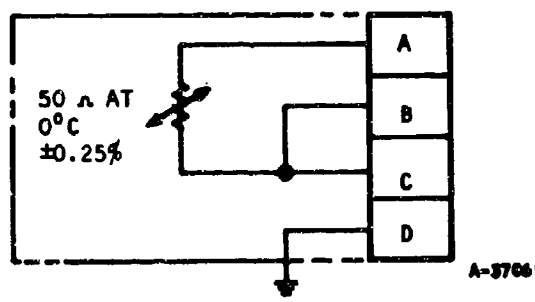
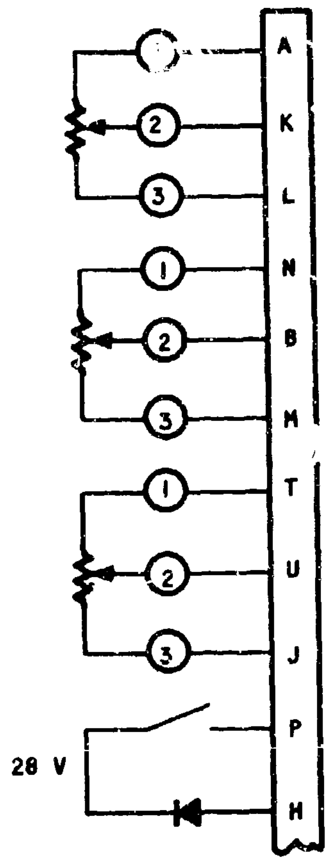


Figure 31. Compressor Discharge Temperature Transducer (P/N 538952) Circuit Schematic



A-37068

Figure 32. Compressor Inlet Pressure Transducer
(P/N 538362-1-1) Circuit Schematic

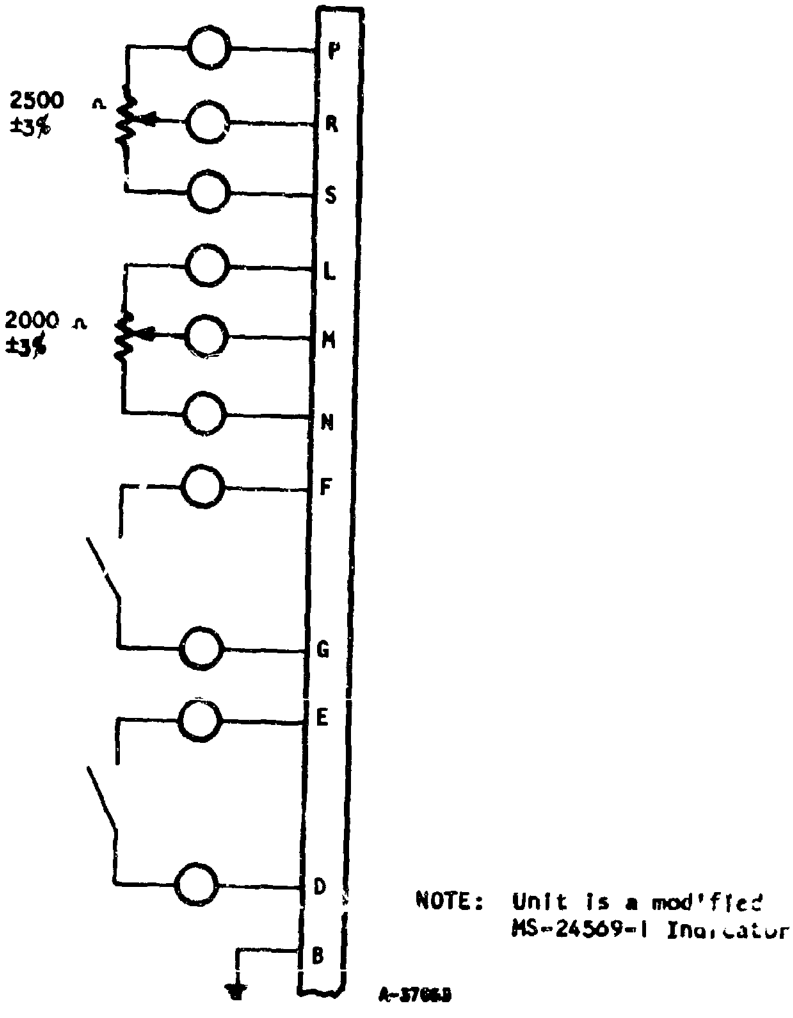


Figure 33. Exhaust Gas Temperature Transducer (P/N 538382) Circuit Schematic

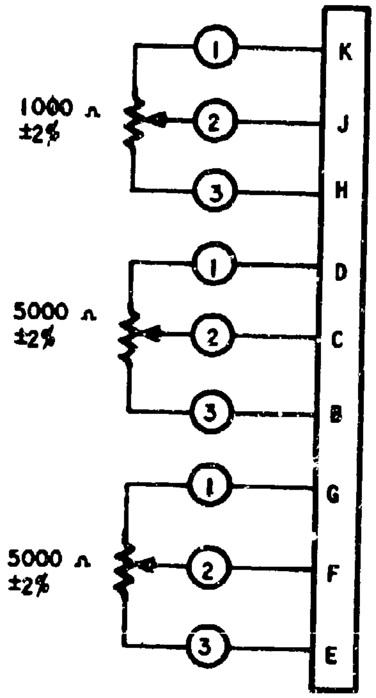


Figure 34. Exhaust Nozzle Area Transducer (P/N 538440-1-1)
Circuit Schematic

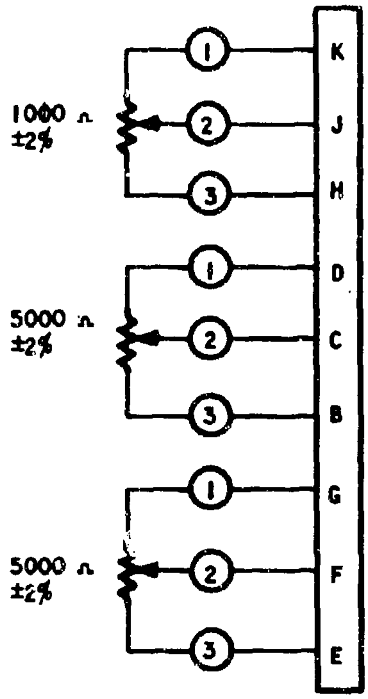


Figure 35. Inlet Guide Vane Transducer (P/N 538⁴'2-1-1)
Circuit Schematic

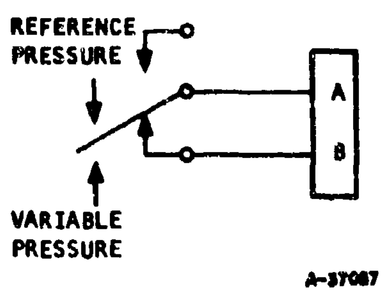


Figure 36. Oil Pressure Switch (P/N 538957) Circuit Schematic

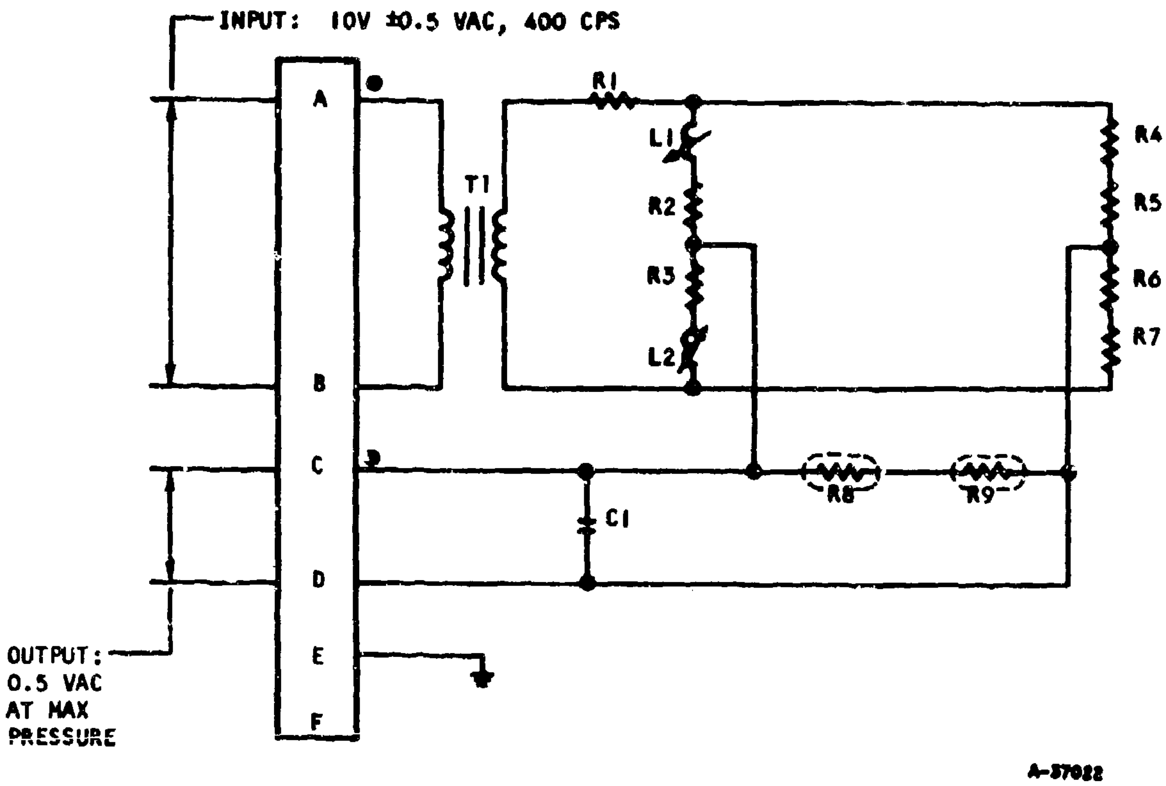


Figure 37. Oil Sump Pressure Transducer (P/N 538947-3) Circuit Schematic

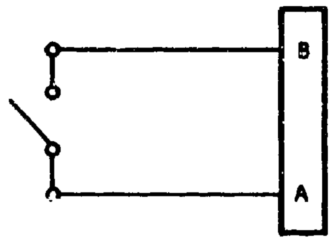


Figure 38. Oil Temperature Switch (P/N 538948) Circuit Schematic

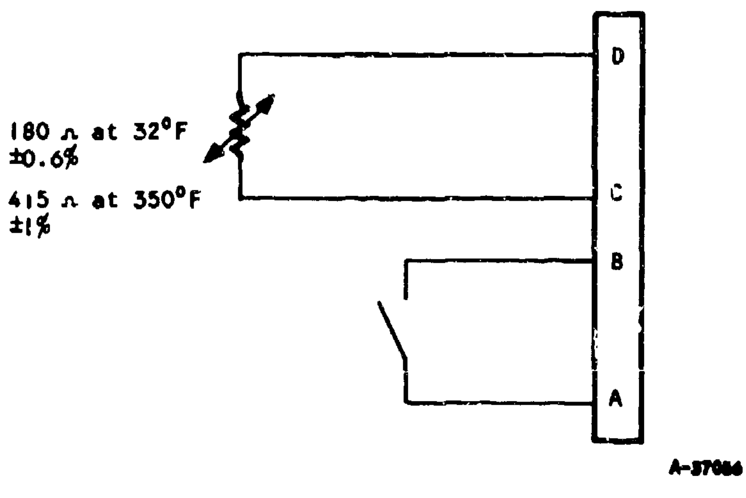


Figure 39. Oil Temperature Transducer (P/N 202187-1)
Circuit Schematic

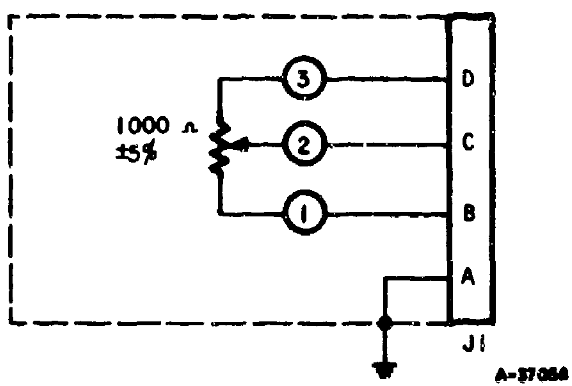
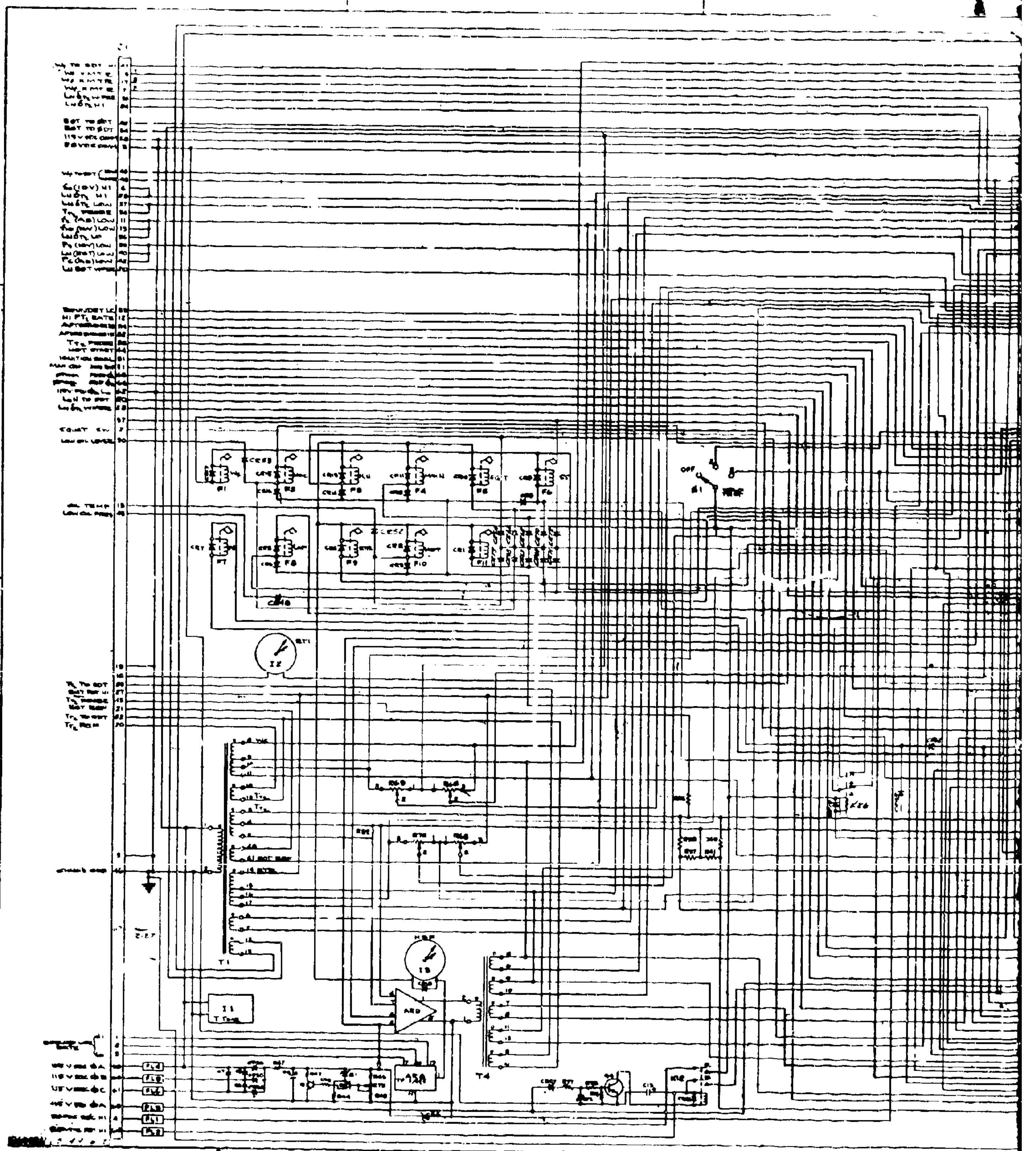
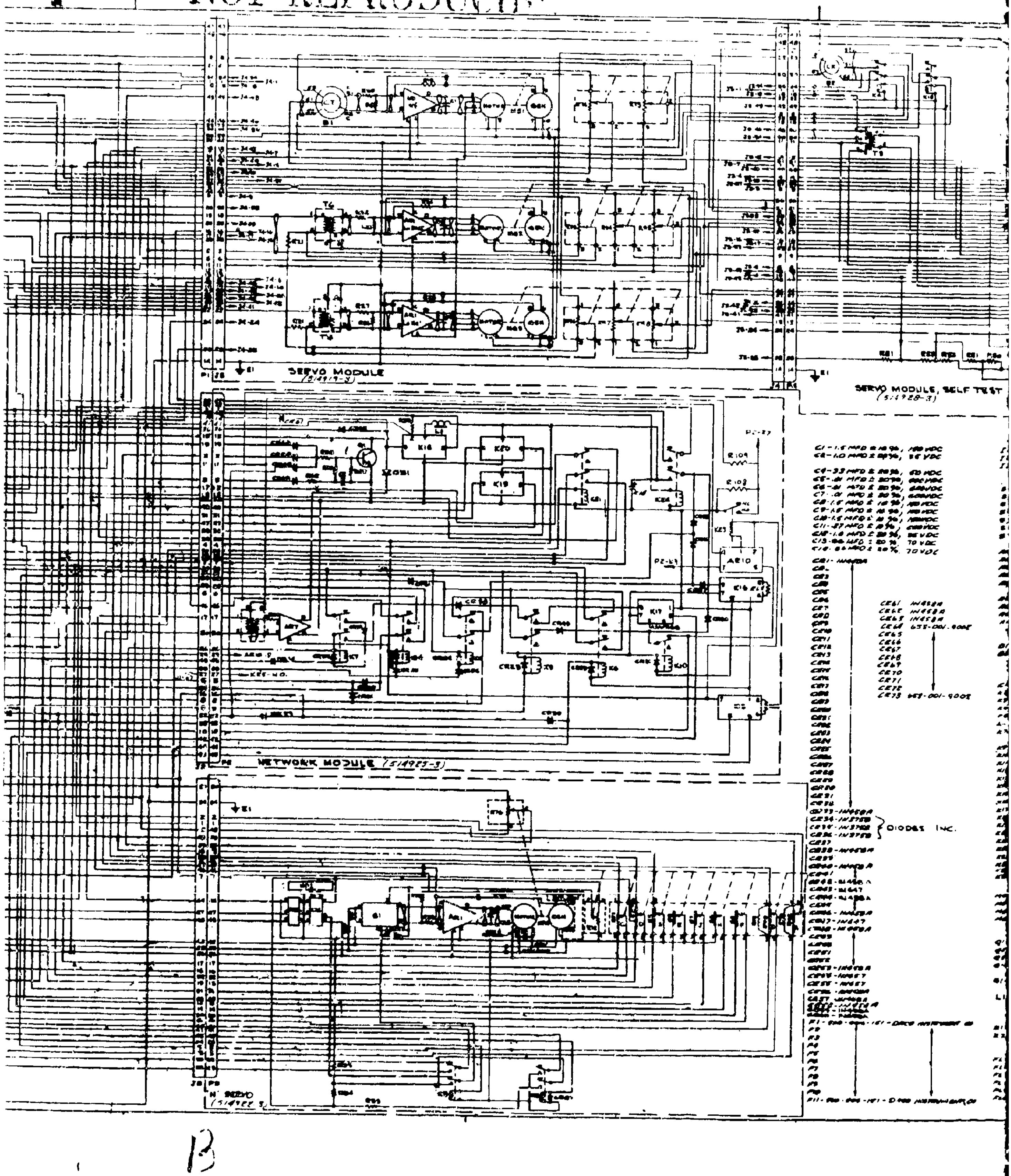


Figure 40. Power Level Angle Transducer (P/N 538444-1-1) Circuit Schematic

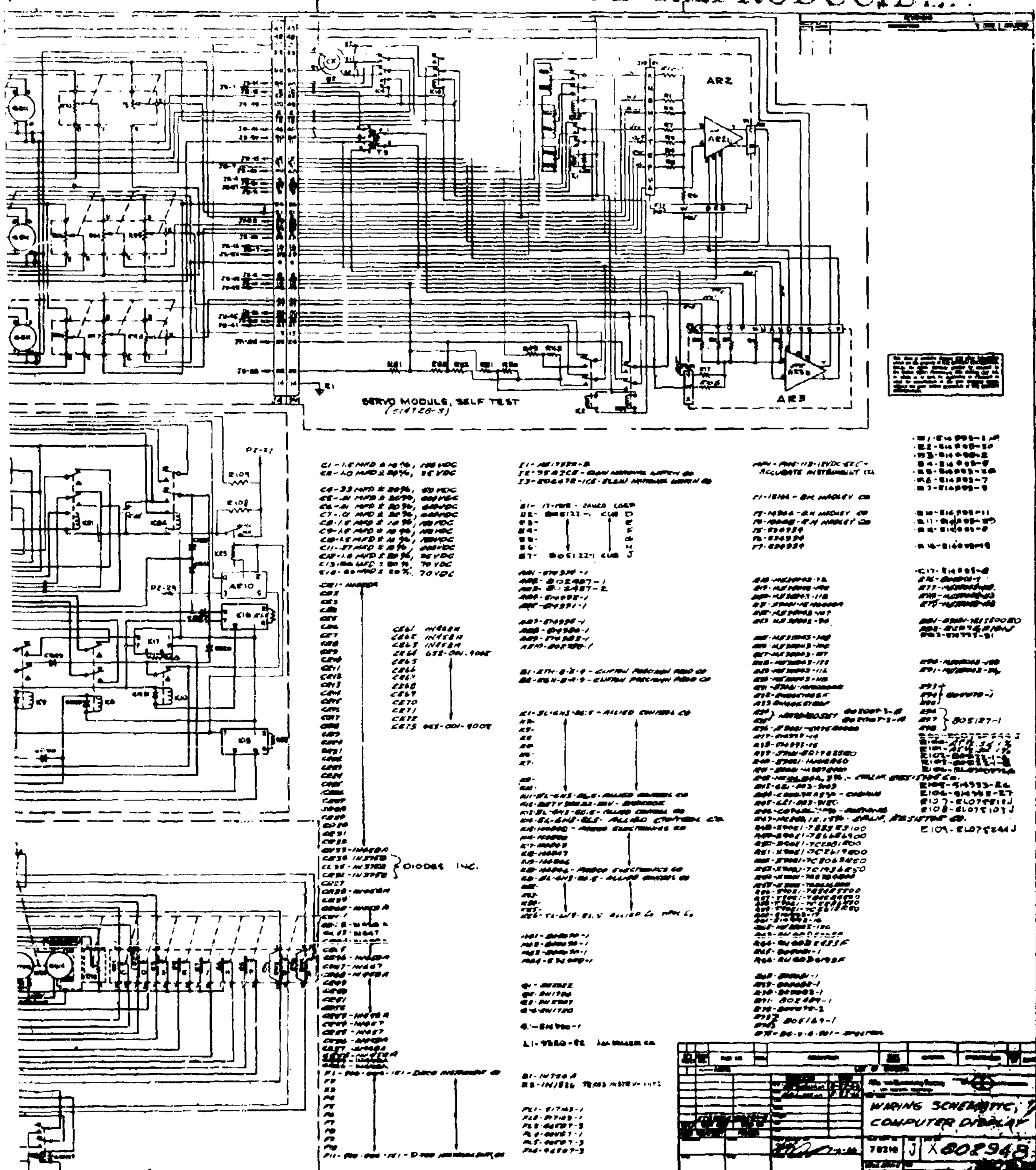


A


SERVO MODULE (514919-3)
SERVO MODULE, SELF TEST (514928-3)
NETWORK MODULE (514925-3)
N SERVO (514922-3)
DIODES INC.

B

NOT REPRODUCIBLE



NOT REPRODUCIBLE

10 9 8

D

AR1 COMPONENT LIST

COMPONENT	PART NO	REMARKS
[illegible]	[illegible]	[illegible]
V	95-001-9001	
[illegible]	[illegible]	MANUFACTURER [illegible]

AR4 COMPONENT LIST

COMPONENT	PART NO	REMARKS
R1	[illegible]	MIL-R-11
R2	[illegible]	MIL-R-11
R3	[illegible]	MIL-R-11
R4	[illegible]	MFG BY CORNING
R5	[illegible]	MFG BY CORNING
R6	[illegible]	MFG BY CORNING
R7	[illegible]	
R8	[illegible]	MIL-R-11
R9	[illegible]	MFG. BY CORNING
R10	[illegible]	MIL-R-11
R11	[illegible]	MIL-R-10509
R12	[illegible]	MIL-R-10509
R13	[illegible]	MIL-R-10509
R14	[illegible]	[illegible]
R15	[illegible]	MFG. BY CORNING
R16	[illegible]	
T1	[illegible]	UNITED TRANSFORMER CO. LOS ANGELES, CALIF. [illegible]
C1	[illegible]	MFG BY SPRAGUE
C2	[illegible]	MFG. BY GULTON IND. INC
C3	[illegible]	
C4	[illegible]	MFG. BY SPRAGUE
C5	[illegible]	MFG BY GULTON INDUSTRIES, INC [illegible]
C6	[illegible]	ALTERNATE FOR C5
C7	[illegible]	[illegible]
C8	[illegible]	[illegible]
C9	[illegible]	MFG BY GULTON IND INC
		MFG BY SPRAGUE S ADAMS, MASS. FED SUPPLY CODE 56289
C10	[illegible]	
CR1	[illegible]	MFG BY TEXAS INSTRUMENTS
CR2	[illegible]	[illegible]
CR3	[illegible]	
CR4	IN646	MFG BY TEXAS INSTRUMENTS, DALLAS, TEXAS FED SUPPLY CODE 56214
CR12	IN758A	MFG BY TEXAS INSTRUMENTS
Q1	2N2221	MFG BY MOTOROLA
Q5	2N2907	MFG BY MOTOROLA
C15	[illegible]	MFG BY SPRAGUE
C17	[illegible]	MFG BY GULTON IND INC

AR5 COMPONENT LIST

COMPONENT	PART NO	REMARKS
[illegible]	[illegible]	MFG BY [illegible] FED. SUPPLY CODE [illegible]
[illegible]	[illegible]	MIL-R-11
[illegible]	[illegible]	MFG BY CORNING
C1	[illegible]	MFG. BY SPRAGUE
C2	[illegible]	MFG BY GULTON IND. INC
C5	[illegible]	MFG BY SPRAGUE, [illegible] FED. SUPPLY CODE
CR1	IN752A	MFG BY TEXAS INSTRUMENTS, DALLAS, TEXAS FED SUPPLY CODE 56214
[illegible]	[illegible]	MFG BY MOTOROLA, PHOENIX, ARIZONA FED SUPPLY CODE 04713

C

AR2a, AR3a COMPONENT LIST

COMPONENT	PART NO	REMARKS
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MFG BY KEMET, CLEVELAND, OHIO FED SUPPLY CODE 05397
C9		△
C10		△

AR7 COMPONENT LIST

COMPONENT	PART NO	REMARKS
[illegible]	[illegible]	MFG BY TEXAS INSTRUMENTS, DALLAS, TEXAS, FED SUPPLY CODE 56214
[illegible]	IN756A	MFG BY MOTOROLA
[illegible]	[illegible]	MFG BY CONTINENTAL DEVICE HAWTHORNE, CALIF FED SUPPLY CODE 07910
[illegible]	2N2907	
[illegible]	2N2222	

AR7 (CONT)

AR8 COMPONENT LIST

COMPONENT	PART NO	REMARKS
[illegible]	[illegible]	[illegible]

B

A

10 9 8

A

NOT REPRODUCIBLE

NOT REP

8 7 6

AR7 (CONT)		
COMP	PART NO.	REMARKS
[illegible]	[illegible]	MFD BY CORNING
P1	[illegible]	[illegible]

AR8 (CONT)		
COMP	PART NO.	REMARKS
R20	[illegible]	MFG BY SPECTROL ELECTRONICS CORP. SAN GABRIEL, CALIF. FED. SUPPLY CODE 02111
R21	[illegible]	
R22	[illegible]	

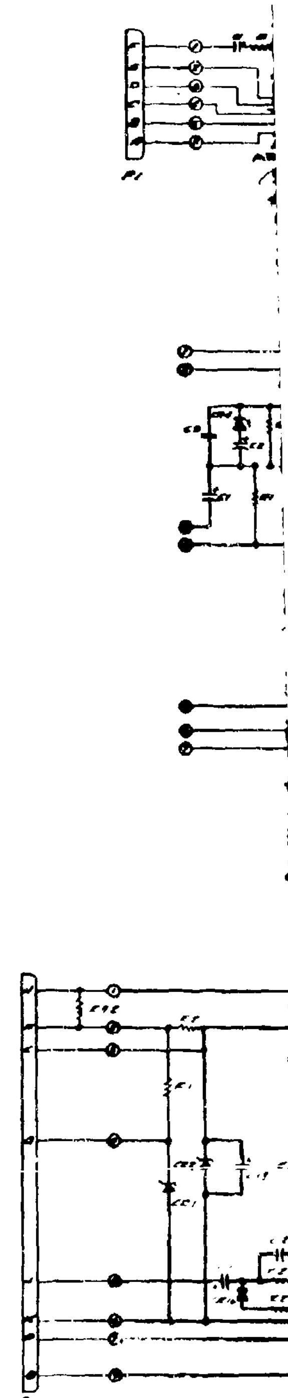
AR8 COMPONENT LIST		
COMPONENT	PART NO.	REMARKS
[illegible]	[illegible]	[illegible]

AR9 COMPONENT LIST		
COMPONENT	PART NO.	REMARKS
R1	[illegible]	
R2	[illegible]	
R3	[illegible]	MFG BY [illegible], BRADFORD, PA. FED. SUPPLY CODE 07116
R4	[illegible]	
R8	[illegible]	
R9	[illegible]	MIL-R-10509
R10	[illegible]	
AR1	[illegible]	
C1	[illegible]	MFG BY SPRAGUE, NORTH ADAMS, MASS.
C2	[illegible]	FED. SUPPLY CODE 56289
C3	[illegible]	[illegible]
C4	[illegible]	
C5	[illegible]	
C6	[illegible]	MFG BY SPRAGUE
C8	[illegible]	MFG BY [illegible]
C9	[illegible]	
CR1	[illegible]	MFG BY MOTOROLA, PHOENIX, ARIZONA
CR2	[illegible]	FED SUPPLY CODE
CR3	[illegible]	[illegible]
Q1	[illegible]	MFG BY TEXAS INSTRUMENTS DALLAS, TEXAS
Q2	[illegible]	
Q3	[illegible]	FED SUPPLY CODE 56289

Q1 COMPONENT LIST		
COMPONENT	PART NO.	REMARKS
S1	[illegible]	
S2	[illegible]	
Q1	2N3569	AMPEREX ELECTRONIC CO. HICKSVILLE, N.Y. FED CODE 79948
Q2	2N3569	
Y1	[illegible]	[illegible] FED CODE [illegible]
T1	14669A	[illegible] FED CODE [illegible]

AR10 COMPONENT LIST		
COMPONENT	PART NO.	REMARKS
R1	[illegible]	
R2	[illegible]	
R3	[illegible]	
R4	[illegible]	
R5	[illegible]	MIL-R-11
R6	[illegible]	
R7	[illegible]	
R8	[illegible]	
R9	[illegible]	
C1	[illegible]	MIL-C-26655/2
CR1	[illegible]	
CR2		
CR3		
CR4		
CR5		
CR6		
CR7		
CR8		
CR9	[illegible]	
CR10	[illegible]	
CR11	[illegible]	
CR12	[illegible]	
Q1	[illegible]	
Q2	[illegible]	
Q3	[illegible]	
Q4	[illegible]	
Q5	[illegible]	MIL-S-19500/255

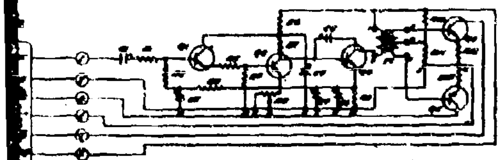
AR9 [illegible]		
[illegible]	[illegible]	[illegible]



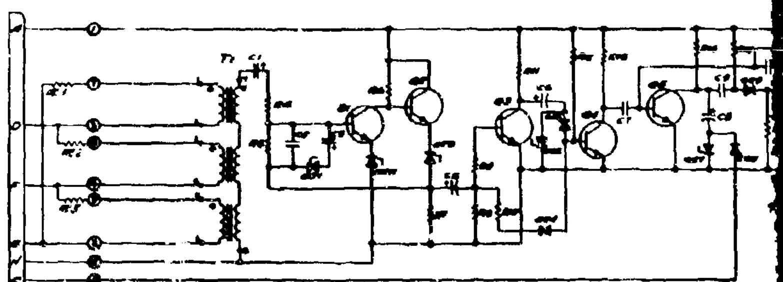
X802948

8 7 6

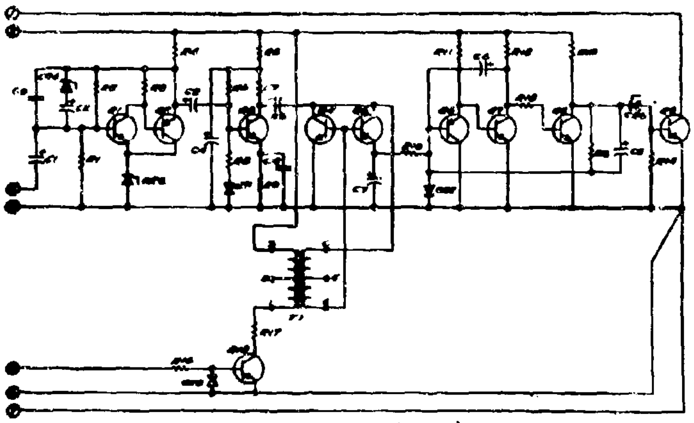
B



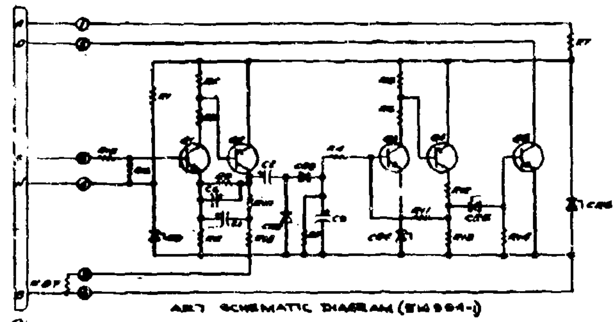
AR1 SCHEMATIC DIAGRAM (SK4934-1)
(SERVO AMP)



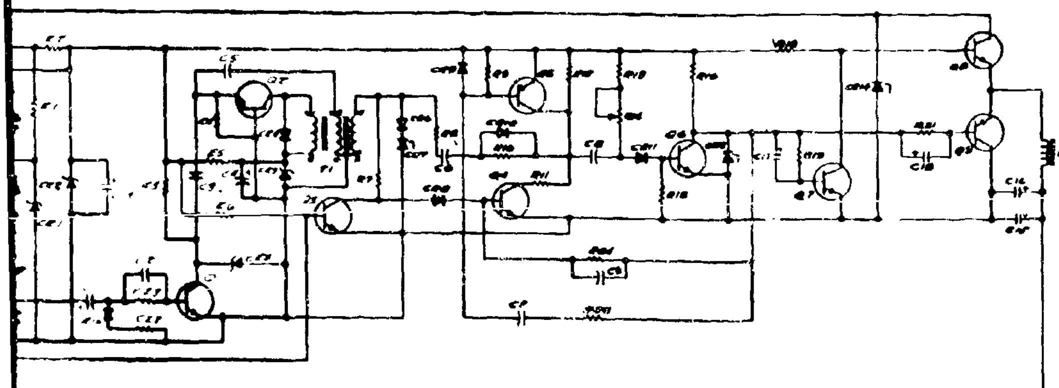
AR6 SCHEMATIC DIAGRAM (SK4948-1)
(CONVERTER PRIMARY)



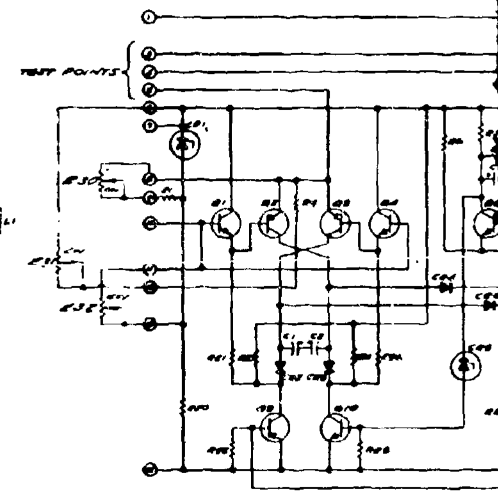
AR2a, AR2b SCHEMATIC DIAGRAM (SK4946-1)
(TRIGGER)



AR7 SCHEMATIC DIAGRAM (SK4904-1)
(TRIGGER MODIFIED)



AR4 SCHEMATIC DIAGRAM (SK4946-1)
(CONVERTER SECONDARY)

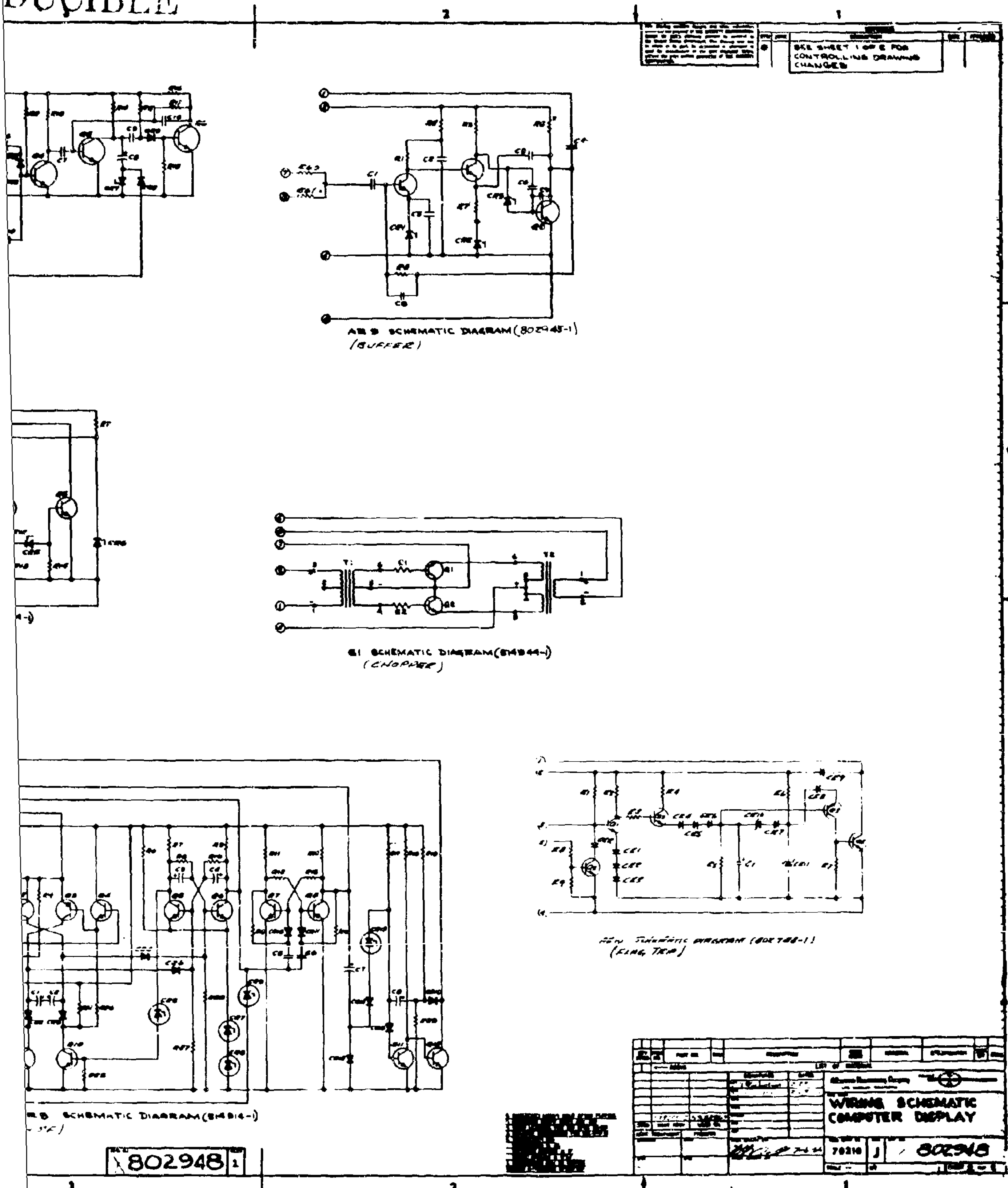


AR8 SCHEMATIC DIAGRA
(NSF)

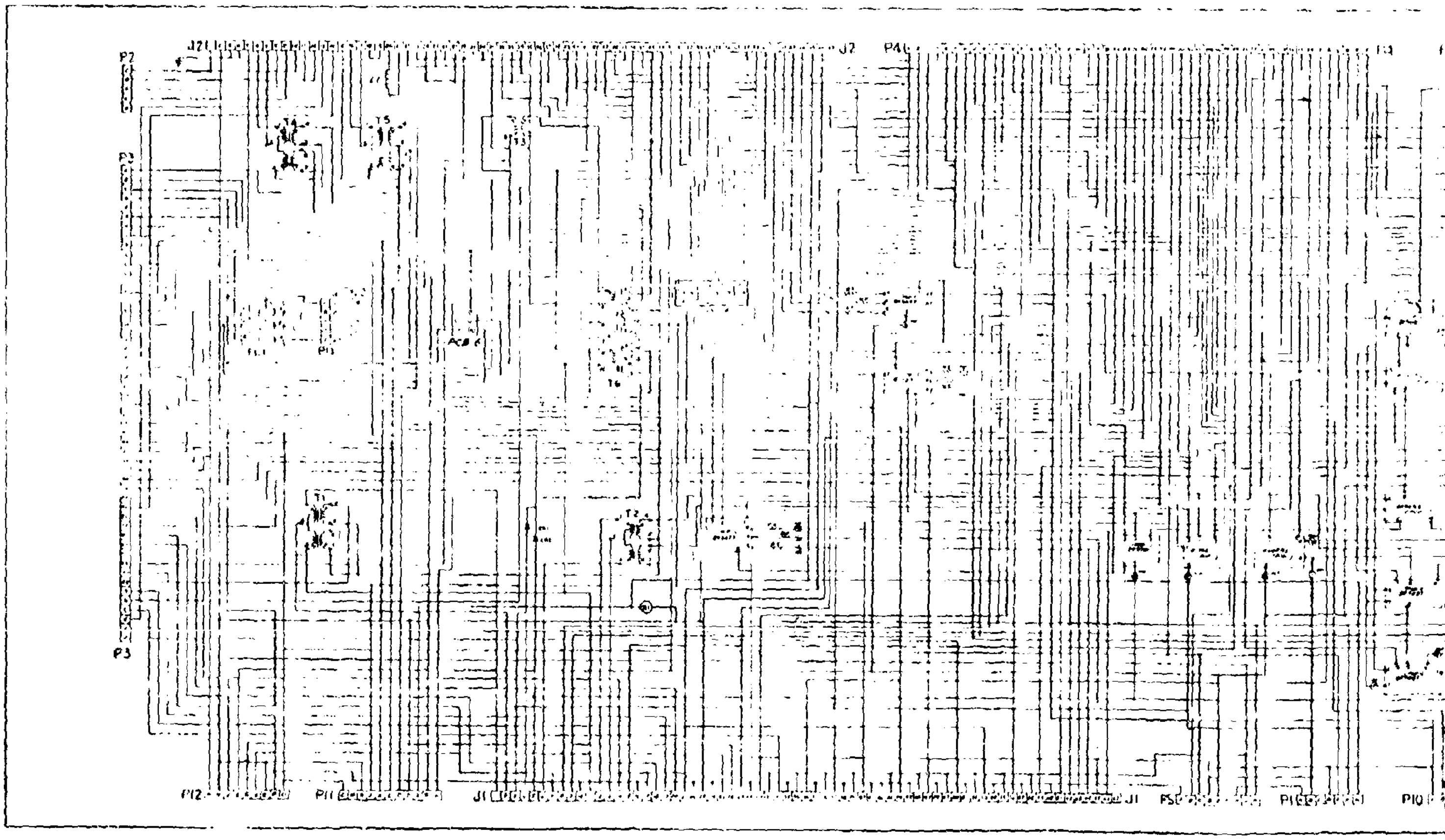
8029

C

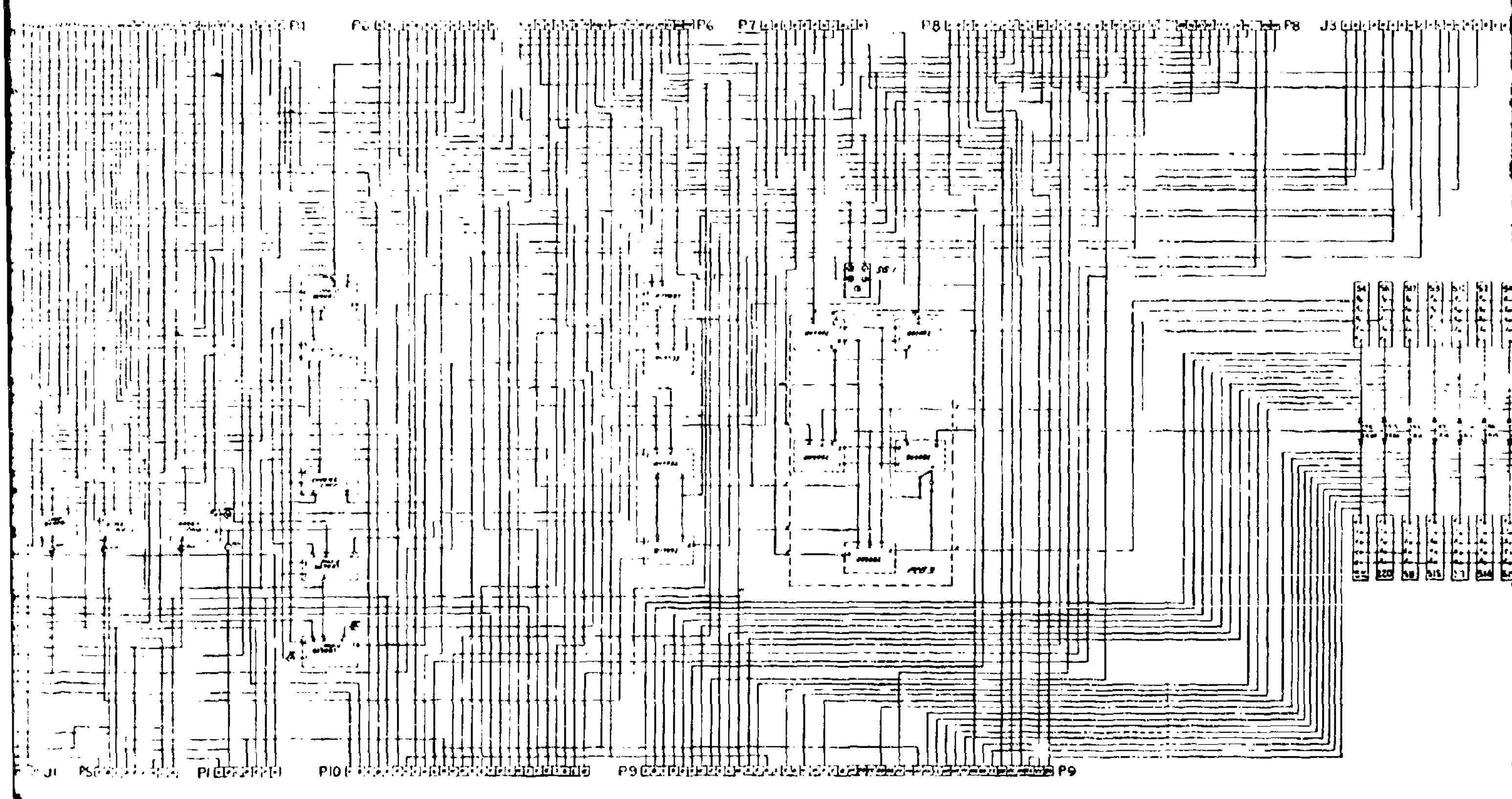
DUCIBLE


SEE SHEET 1 OF 2 FOR CONTROLLING DRAWING CHANGES
AR 9 SCHEMATIC DIAGRAM (802945-1)
(BUFFER)
G1 SCHEMATIC DIAGRAM (814944-1)
(CHOPPER)
SCHEMATIC DIAGRAM
(RING TRIP)
SCHEMATIC DIAGRAM
WIRING SCHEMATIC
COMPUTER DISPLAY
70210
802948
802948

D

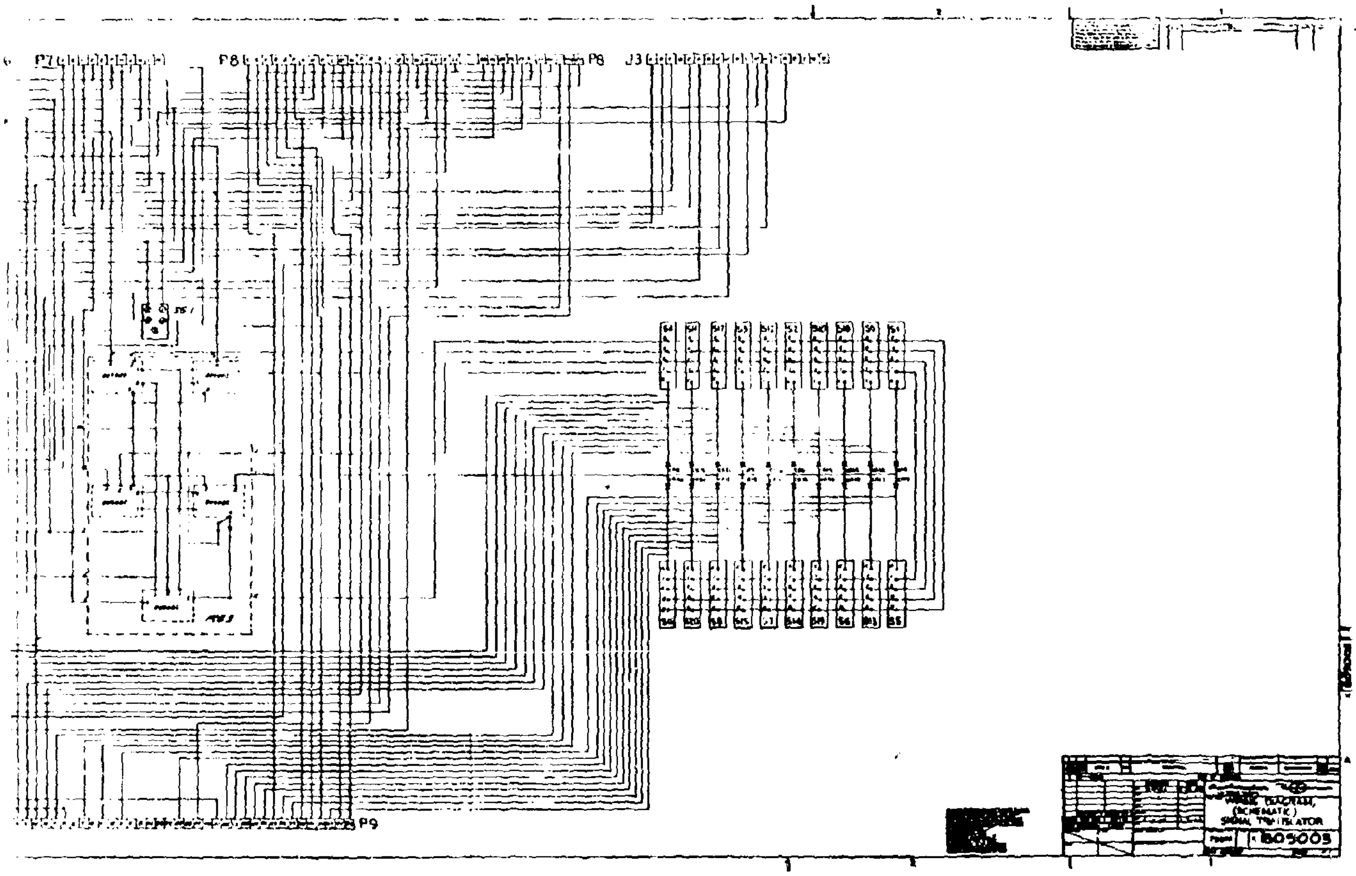


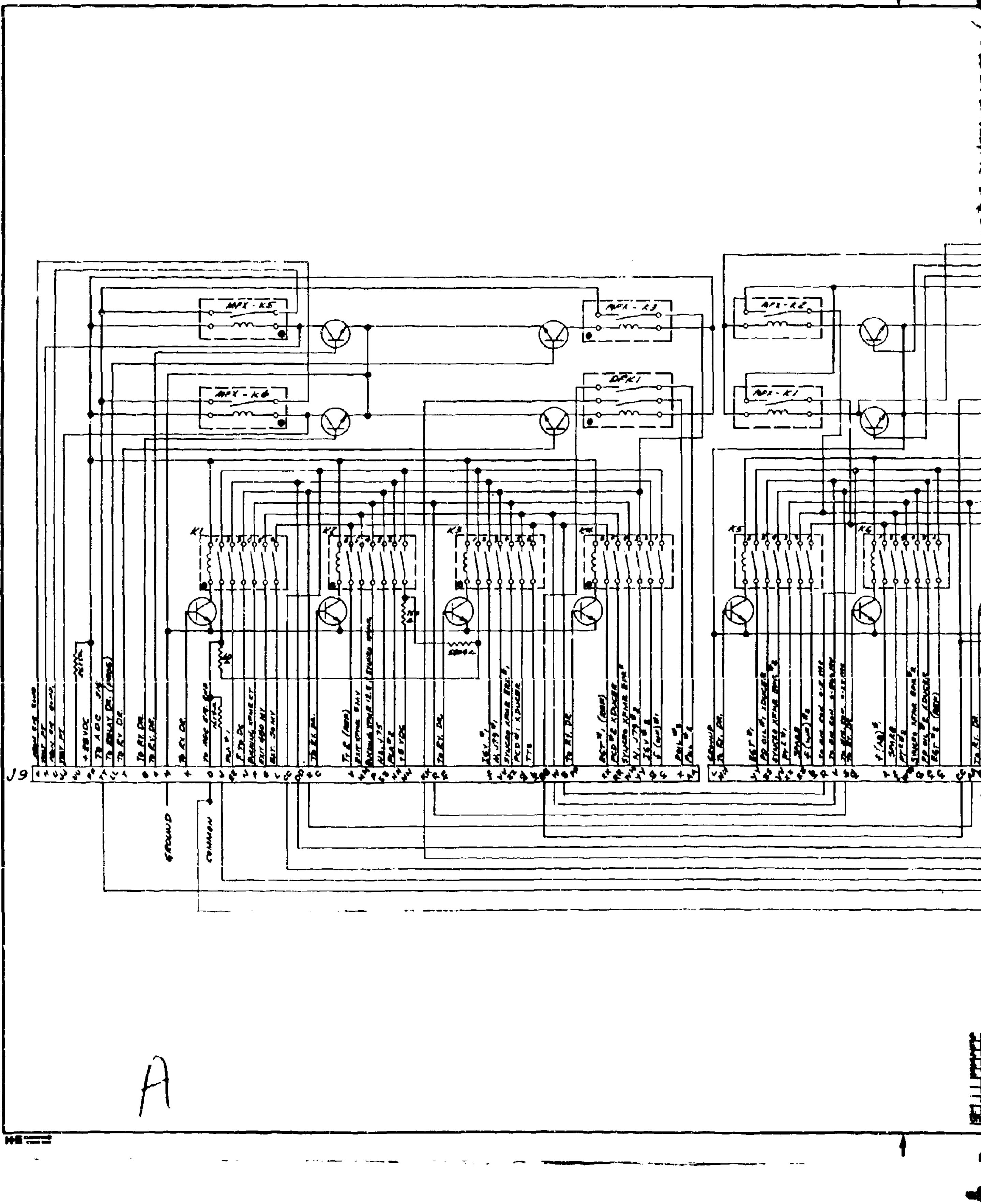
A


P1
P6
P6
P7
P8
P8
J3
J1
P5
P1
P10
P9
P9

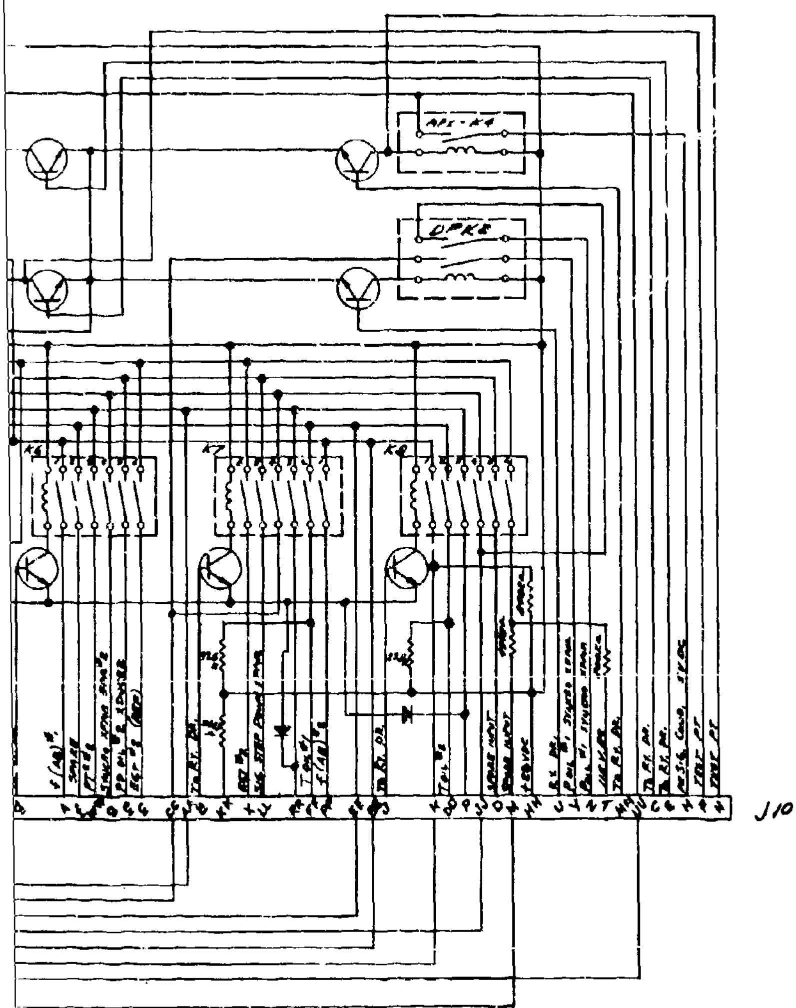
DUCIBLE

NOT REPRODUCIBLE




MPX - K5
MPX - K3
MPX - K2
MPX - K6
DFK1
MPX - K1
K1
K2
K3
K4
K5
K6
J9
GROUND
COMMON
A

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
A	SEE REVISION NOTICE		



B

QTY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL	SPECIFICATION	UNIT WT
← ASSYS				LIST OF MATERIAL				

REQD	NEXT ASSY	USED ON
1		

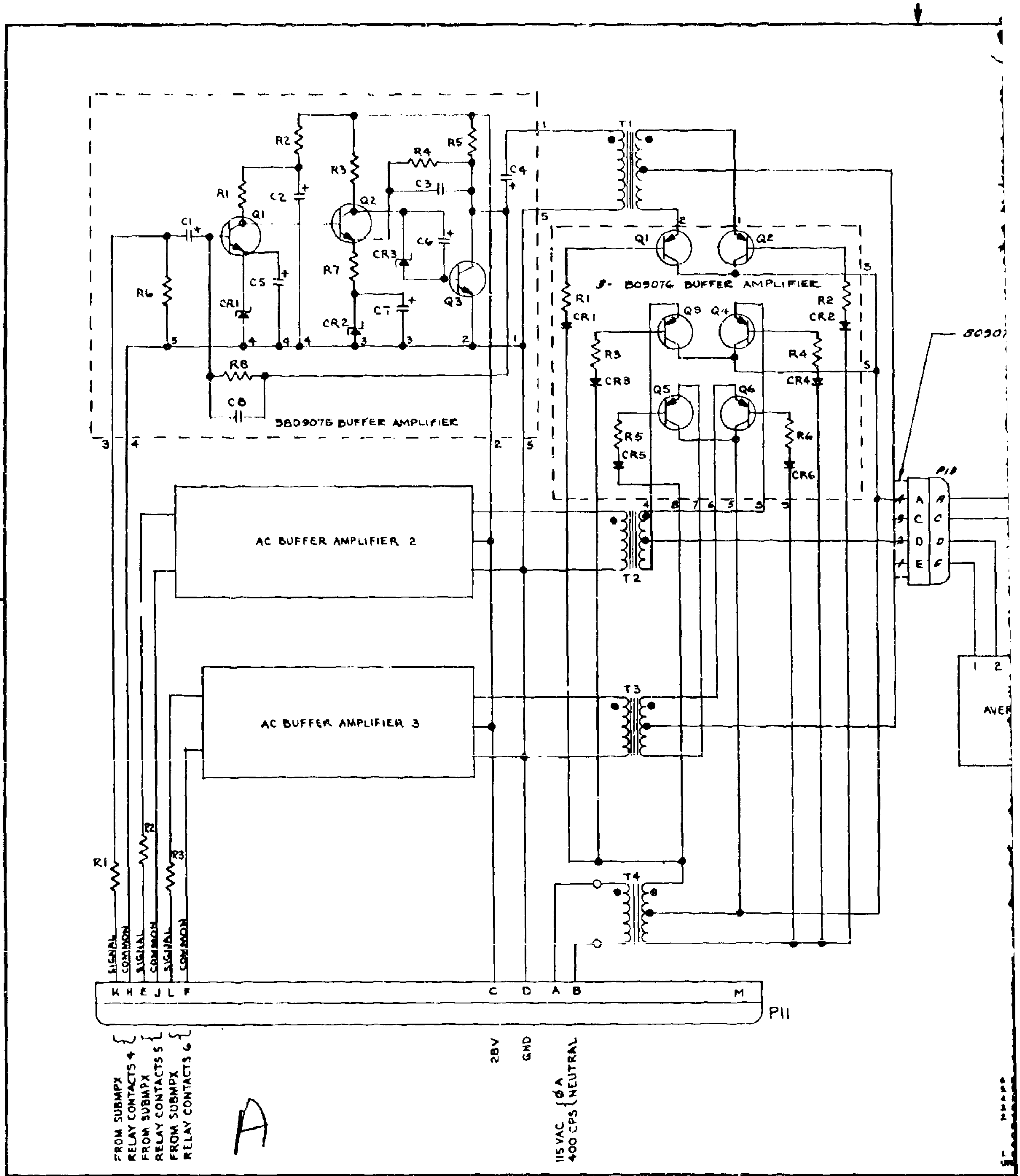
HEAT TREATMENT | PROCESS

SIGNATURES | DATES

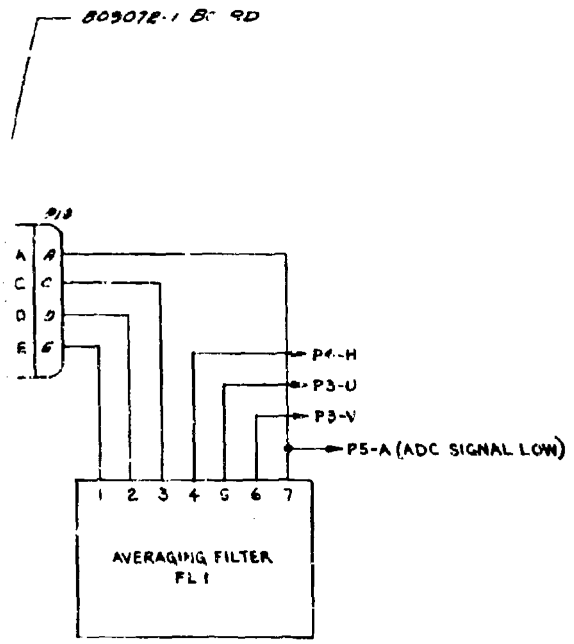
WIRING DIAGRAM, SCHEMATIC
RELAYS

70210 | D | X809079

SCALE NONE | WT | SHEET 1 OF 1


5BD9076 BUFFER AMPLIFIER
5- BD9076 BUFFER AMPLIFIER
AC BUFFER AMPLIFIER 2
AC BUFFER AMPLIFIER 3
T1
T2
T3
T4
P10
P11
AVER
SIGNAL
COMMON
K H E J L F
C D A B M
FROM SUBMPX RELAY CONTACTS 4
FROM SUBMPX RELAY CONTACTS 5
FROM SUBMPX RELAY CONTACTS 6
28V
GND
115 VAC 400 CPS
ØA
NEUTRAL
A

SYM	DESCRIPTION	DATE	APPROVAL
A	SEE REVISION NOTICE	5-7-64	
B	SEE REVISION NOTICE	8-4-64	



COMPONENT LIST

809075 AMPLIFIER	809076 AMPLIFIER
C1 = CS13AD220K	CR1 = IN645
C2 = CS13AF010K	CR2 = IN645
C3 = CT10D-511K GULTON	CR3 = IN645
C4 = CS13AF220M	CR4 = IN645
C5 = CS13AD8R2M	CR5 = IN645
C6 = CS13AF010K	CR6 = IN645
C7 = CS13AE150M	
C8 = CT10D-100K GULTON	Q1 = 2N2336
	Q2 = 2N2336
CR1 = IN713A	Q3 = 2N2336
CR2 = IN717A	Q4 = 2N2336
CR3 = IN720A	
	R1 = RL07AD223J
Q1 = 2N910	R2 = RL07AD223J
Q2 = 2N910	R3 = RL07AD223J
Q3 = 2N910	R4 = RL07AD223J
	R5 = RL07AD223J
R1 = RL07AD104J	R6 = RL07AD223J
R2 = RL07AD393J	
R3 = RL07AD623J	R1 = RN65E1004F MIL-R-10509/2
R4 = RL07AD513J	R2 = RN65E2002F MIL-R-10509/2
R5 = RL07AD752J	R3 = RN65E2003F MIL-R-10509/2
R6 = RL07AD104J	
R7 = RL07AD510J	J1 = MM11-22PGDS (CONTINENTAL)
R8 = RN65E2003F	
	T1 = 15030 HADLEY
FL1 = [illegible]	T2 = 15030 HADLEY
	T3 = 15030 HADLEY
	T4 = 15031 HADLEY

B

QTY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION
	← ASSY					

LIST OF MATERIAL

6. DIMENSION LIMITS HELD AFTER PLATING.
5. MACHINED FILLET RAD. [illegible]
4. BURR CONTROL PER AIR SPEC [illegible]
3. SURFACE ROUGHNESS PER MIL-STD-10
2. TOLERANCES ON: DIMENSIONS ± .01; CHAMFER ANGLES ± 5°; OTHER ANGLES ± 0°30'
1. DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.

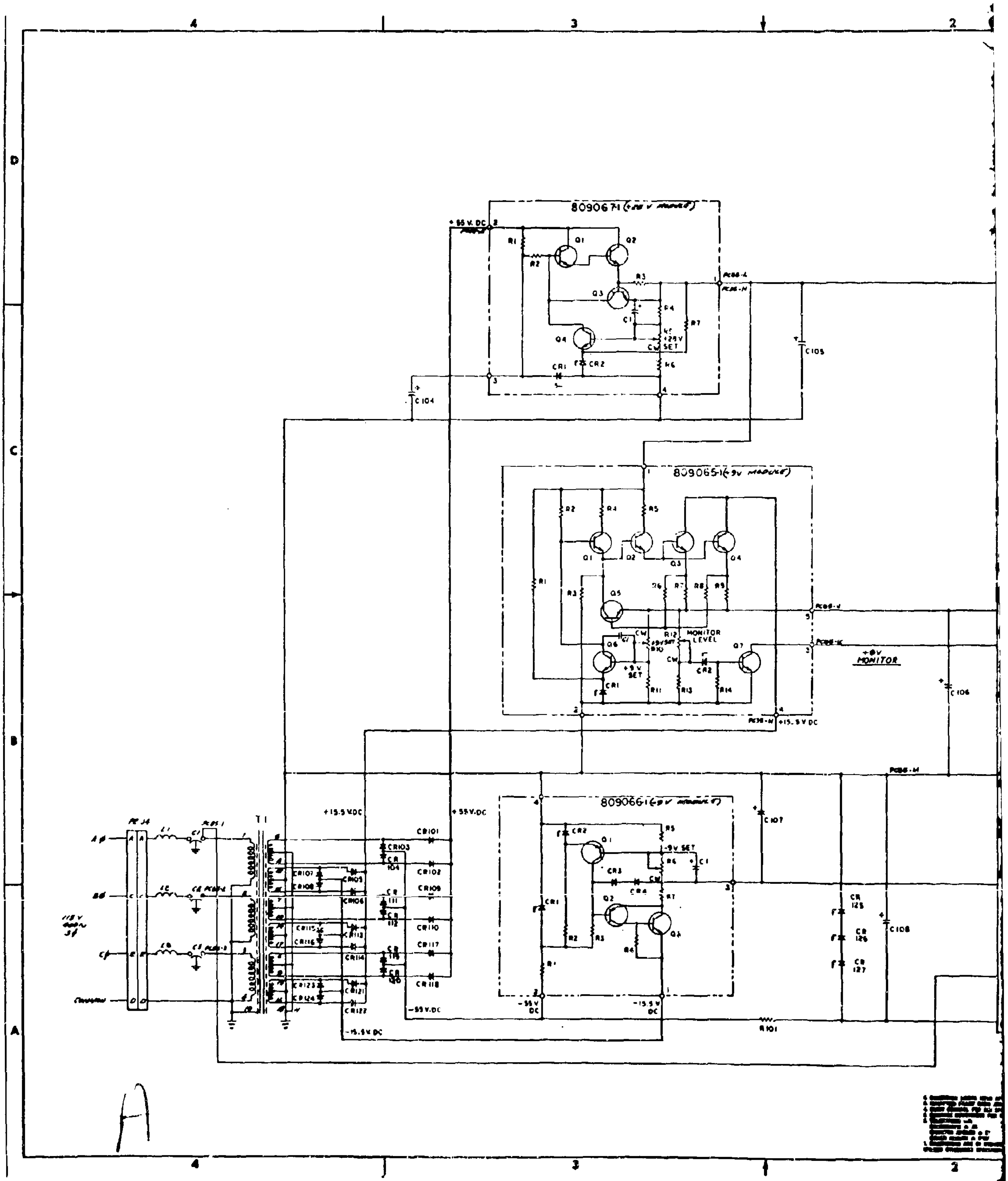
SIGNATURES / DATES: DR [signature] 12-21-63; [signature]

AiResearch Manufacturing Company, Los Angeles, California

WIRING DIAGRAM, SIGNAL CONDITIONERS

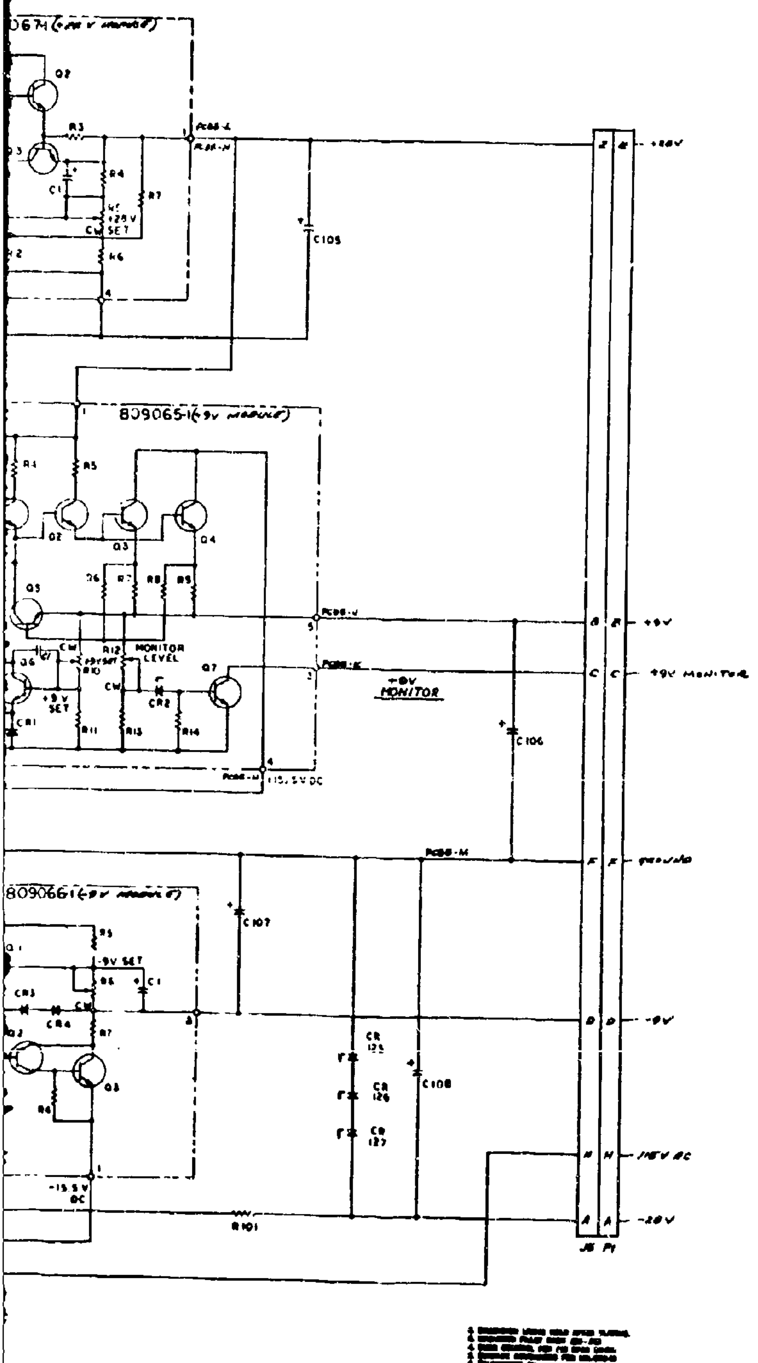
CODE IDENT NO. 70210 | SIZE D | DWG NO. X809071

SCALE | SHEET 1 OF 1



809067-1
809065-1
809066-1
+55 V. DC
+9V MONITOR
MONITOR LEVEL
+9 V SET
-9 V SET
+15.5 V DC
-55 V DC
-15.5 V DC
T1
C104
C105
C106
C107
C108
R101

A | SEE REVISION NOTICE



809067 - +28 V. CIRCUITS	INTER-CONNECTING CIRCUITRY
Q1 - 2N910	T1 - TRANSFORMER, POWER
Q2 - 2N2993	
Q3 - 2N731	
Q4 - 2N2222	
	CR101 - 1N3758
CR1 - 1D36 B	CR102
CR2 - 1N3514	CR103
	CR104
C1 - .15 µf	CR105
	CR106
R1 - 2.5K ±3% 1W RS-1A	CR107
R2 - 3.9K ±5% 1/4W	CR108
R3 - 1.5K ±3% 1W RS-1A	CR109
R4 - 4.7K ±1% 1W RS-1A	CR110
R5 - 2.0K POT	CR111
R6 - 1.3K ±1% 1/4W RS-1/4	CR112
R7 - 6.2K ±5% 1/2W	CR113
	CR114
PA 56947 HEAT SINK	CR115
	CR116
	CR117
	CR118
	CR119
	CR120
	CR121
	CR122
	CR123
	CR124 - 1N3758
	CR125 - 1D 9/A, 9.1V ±5%
	CR126 - 1D 9/B, 9.1V ±5%
	CR127 - 1D 9/B, 9.1V ±5%

809065 - +9 V. CIRCUITS

Q1 - 2N2222	C1 - .047µf 600 VDC
Q2 - 2N2222	C2 - .047µf 600 VDC
Q3 - 2N2983	C3 - .047µf 600 VDC
Q4 - 2N2983	C101 - .01 µf 600 VDC
Q5 - 2N2222	C102 - .01 µf 600 VDC
Q6 - 2N731	C103 - .01 µf 600 VDC
Q7 - 2N914	C104 - 22 µf 70 VDC
	C105 - 33 µf 50 VDC
CR1 - 1N3514	C106 - 180 µf
CR2 - 1N3514	C107 - 160 µf
	C108 - 33 µf 50 VDC
C1 - .0015 µf 100V CT100-152K Guilton	
R1 - 2.2K ±3% 1W RS-1A	R101 - 820 Ω 3 W
R2 - 4.3K ±5% 1/2W	
R3 - 10K ±5% 1/4W	
R4 - 4.7K ±5% 1/2W	
R5 - 200 Ω ±5% 2W	L1 - 500mH
R6 - 100 Ω ±5% 1/4W	L2 - 500mH
R7 - 0.75 Ω ±3% 1W RS-1A	L3 - 500mH
R8 - 100 Ω ±5% 1/4W	
R9 - 0.75 Ω ±3% 1W RS-1A	
R10 - 500 Ω POT	
R11 - 1.1K ±1% 1/4W RS-1/4	
R12 500 Ω POT	
R13 1.5K ±5% 1/4W	
R14 10K ±5% 1/4W	
TX BP-017 028-1 DISSIPATOR	
TX BP-038-037-1 DISSIPATOR	
PA 56346 MOUNTING PLATE	

809066 - -9 V CIRCUITS

Q1 - 2N2907
Q2 - 2N2907
Q3 - 2N2983

CR1 - 1D18 B DIODES INC.
CR2 - 1N3514
CR3 - 1N3758
CR4 - 1N3758

C1 - 0.15 µf

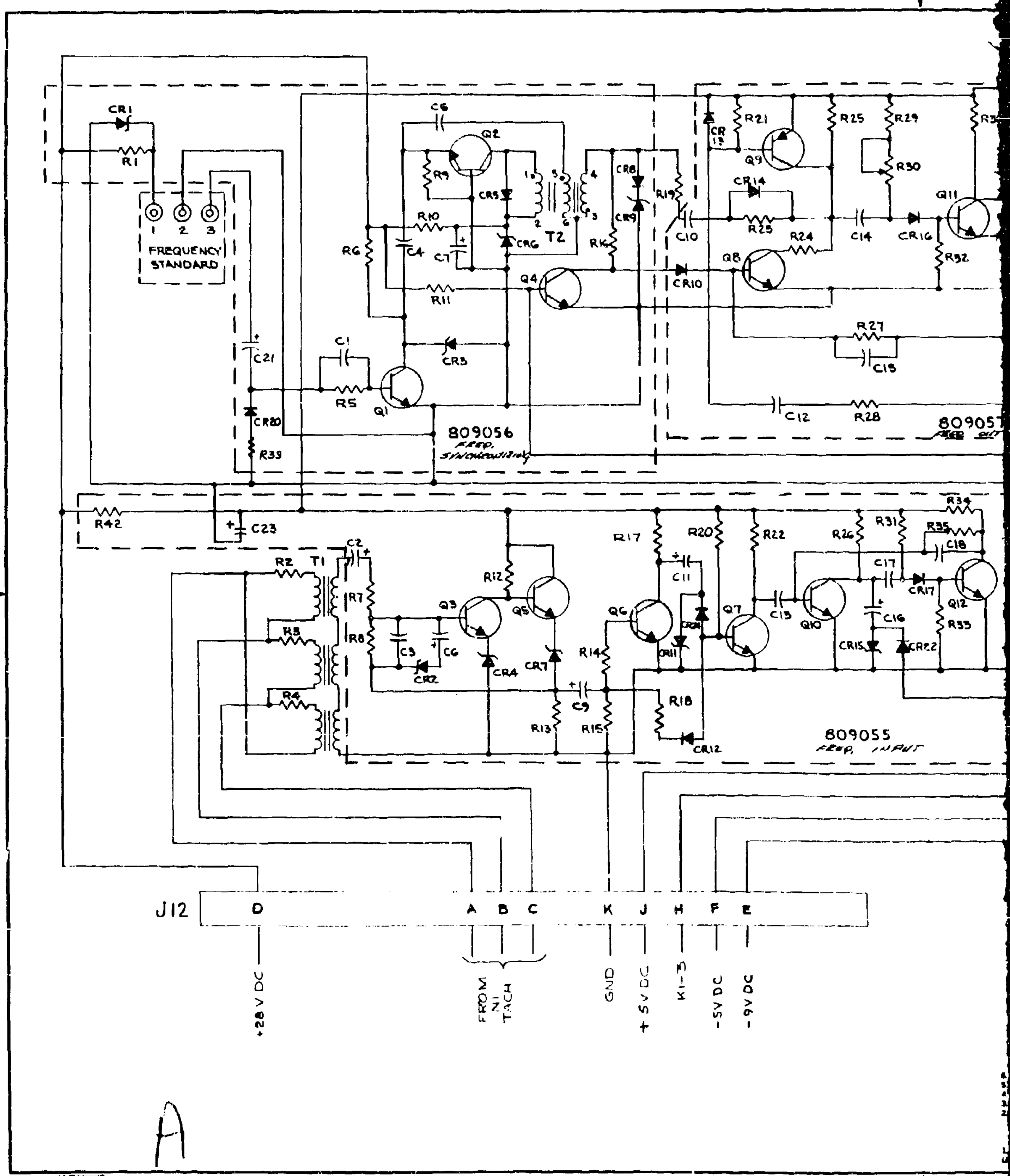
R1 - 2K ±3% 1W RS-1A
R2 - 2.2K ±3% 1W RS-1A
R3 - 4.7K ±3% 1W RS-1A
R4 - 1K ±5% 1/4W
R5 - 1.1K ±1% 1/4W RS-1/4
R6 - 500 Ω POT
R7 - 1.5 Ω ±3% 1W RS-1A

B

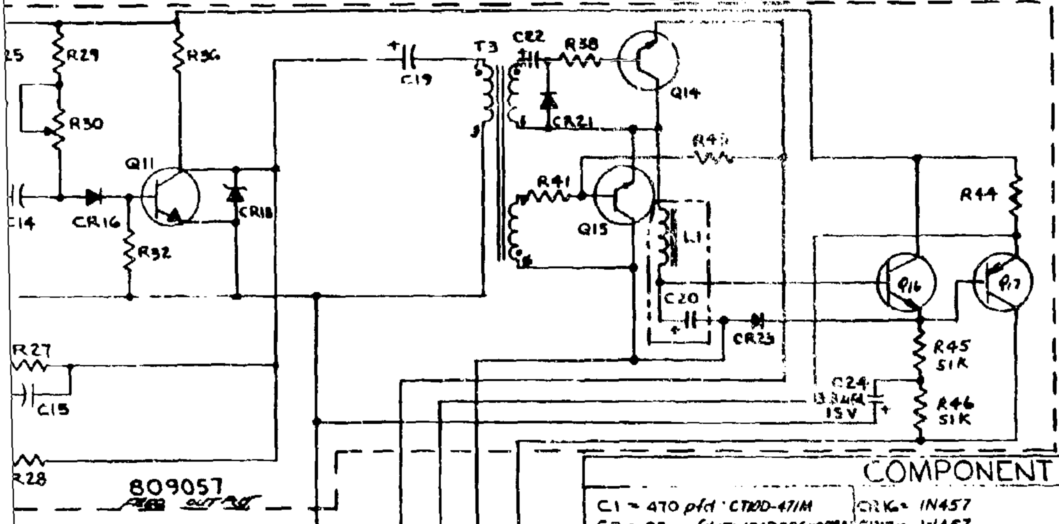
WIRING DIAGRAM - SCHEMATIC
POWER SUPPLY

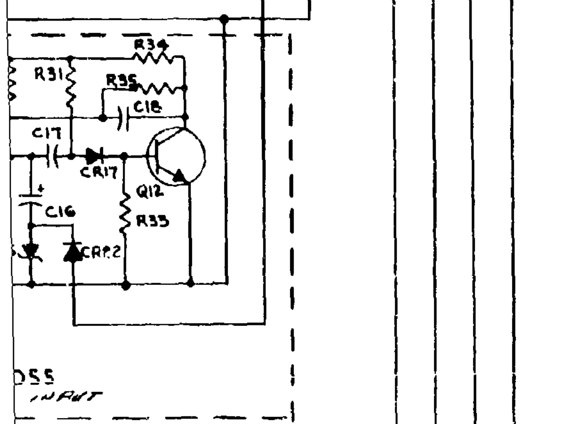
70210 | E | X809061

X809061


FREQUENCY STANDARD
809056
FREQ. SYNCHRONIZING
809057
809055
FREQ. INPUT
J12
D
A
B
C
K
J
H
F
E
+28 V DC
FROM N1 TACH
GND
+ 5 V DC
K1-3
-5V DC
-9V DC

A





COMPONENT LIST

C1 = 470 pfd CT100-471M
C2 = 22 ufd 15V 150D226X0015B2
C3 = .001 ufd CT100-102M
C4 = .0022 ufd CT10
C5 = .0022 Mfd CT10
C6 = 1 ufd 35V 150D105X0035A2
C7 = 1 ufd 35V 150D105X0020A2
~~C8 = 3.3 ufd 15V 150D335X0015A2~~
C9 = 22 ufd 15V 150D226X0015B2
C10 = 470 pfd CT100-471M
C11 = .068 ufd [illegible]
C12 = .0047 ufd CT10
C13 = .0047 ufd 35VDC CT10
C14 = 0.10 ufd 200V BAL 9 TYPE PKM
C15 = 100 pfd CT100-101M
C16 = 1 ufd 35V 150D105X0035A2
C17 = .01 ufd CT10D
C18 = 100 pfd CT100-101M
C19 = 22 ufd 15V 150D105X0015A2
C20 = 10 ufd 20V 150D106X0020R2
C21 = 1 ufd 35VDC
C22 = 6.8 ufd 6VDC CS13AB [illegible]
C23 = 6.8 ufd 35VDC CS13AF6R8K
C24 = 3.3 ufd 15V
CR1 = IN759A
CR2 = IN752A
CR3 = IN752A
CR4 = IN752A
CR5 = IN645
CR6 = IN758A
CR7 = IN752A
CR8 = IN914A
CR9 = IN749A
CR10 = IN914A
CR11 = IN749A
CR12 = IN457
CR13 = IN457
CR14 = IN914A
CR15 = IN749A

CR16 = IN457
CR17 = IN457
CR18 = IN758A
~~CR19 = IN752A~~
CR20 = IN457
CR21 = IN457
CR22 = IN457
CR23 =
CR24 = IN457
L1 = 14758
Q1 = 2N2221
Q2 = 2N2221
Q3 = 2N2222
Q4 = 2N2221
Q5 = 2N2221
Q6 = 2N2221
Q7 = 2N2221
Q8 = 2N2221
Q9 = 2N ~~2222~~
Q10 = 2N2221
Q11 = 2N2221
Q12 = 2N2221
~~Q13 = 2N2221~~
Q14 = 2N2432
Q15 = 2N2432
Q16 = 2N2221
Q17 = 2N2907
R1 = MS35043-54 (2K)
R2 = 621-002-9171 (2000Ω) 3W
R3 = 621-002-9171
R4 = 621-002-9171
R5 = RL07AD103J (10K)
R6 = MS35043-104 (51K)
R7 = RL07AD103J (10K)
R8 = RL07AD104J (100K)

R9 = RL07AD102J (1K)
R10 = MS35043-111 (10KΩ)
R11 = RL07AD513J (51K)
R12 = RL07AD203J (20K)
R13 = MS35043-98 (3K)
R14 = RL07AD222J (22K)
R15 = RL07AD302J (3K)
R16 = RL07AD202J (2K)
R17 = MS35043-111 (10K)
R18 = RL07AD102J (1K)
R19 = MS35043 -
R20 = RL07AD513J (51K)
R21 = RL07AD204J (200K)
R22 = MS35043-111 (10K)
R23 = MS35043-122 (30K)
R24 = RN60E1001F (1K)
R25 = RN60E1002F (10K)
R26 = MS35043-98 (3K)
R27 = RL07AD513J (51K)
R28 = RL07AD113J (11K)
R29 = RN60E2322F ( )
R30 = 50-2-1-502 (5K)
R31 = RL07AD513J (51K)
R32 = RL07AD204J (200K)
R33 = RL07AD104J (100K)
R34 = MS35043-104 (5.1K)
R35 = RL07AD513J (51K)
R36 = MS35043-99 (2.4K)
~~R37 = MS35043-104 (5.1K)~~
R38 = RL07AD392J (3.9K)
R39 = RL07AD103J (10K)
R40 = RL07AD512J (5.1K)
R41 = RL07AD392J (3.9K)
R42 = MS35043-70 (200Ω)
R43 = RL07AD303J (30K)
R44 = RL07AD513J (51K)
T1 = 14735
T2 = PIP-3 (UTC)
T3 = DIT 278 (UTC)

QTY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION
	← ASSY			LIST OF MATERIAL		

REVISIONS

SYM	DESCRIPTION	DATE	APPROVED

6. DIMENSION LIMITS HELD AFTER PLATING.
5. MACHINED FILLET RADII .010-.015
4. BURR CONTROL PER AIR SPEC SC-033
3. SURFACE ROUGHNESS PER MIL-STD-10
2. TOLERANCES ON: DIMENSIONS ± .01, CHAMFER ANGLES ± 5°, OTHER ANGLES ± 0°30'
1. DIMENSIONS ARE IN INCHES. UNLESS OTHERWISE SPECIFIED.

SIGNATURES	DATES
D. Stanton	12-30-61
	5-16-62

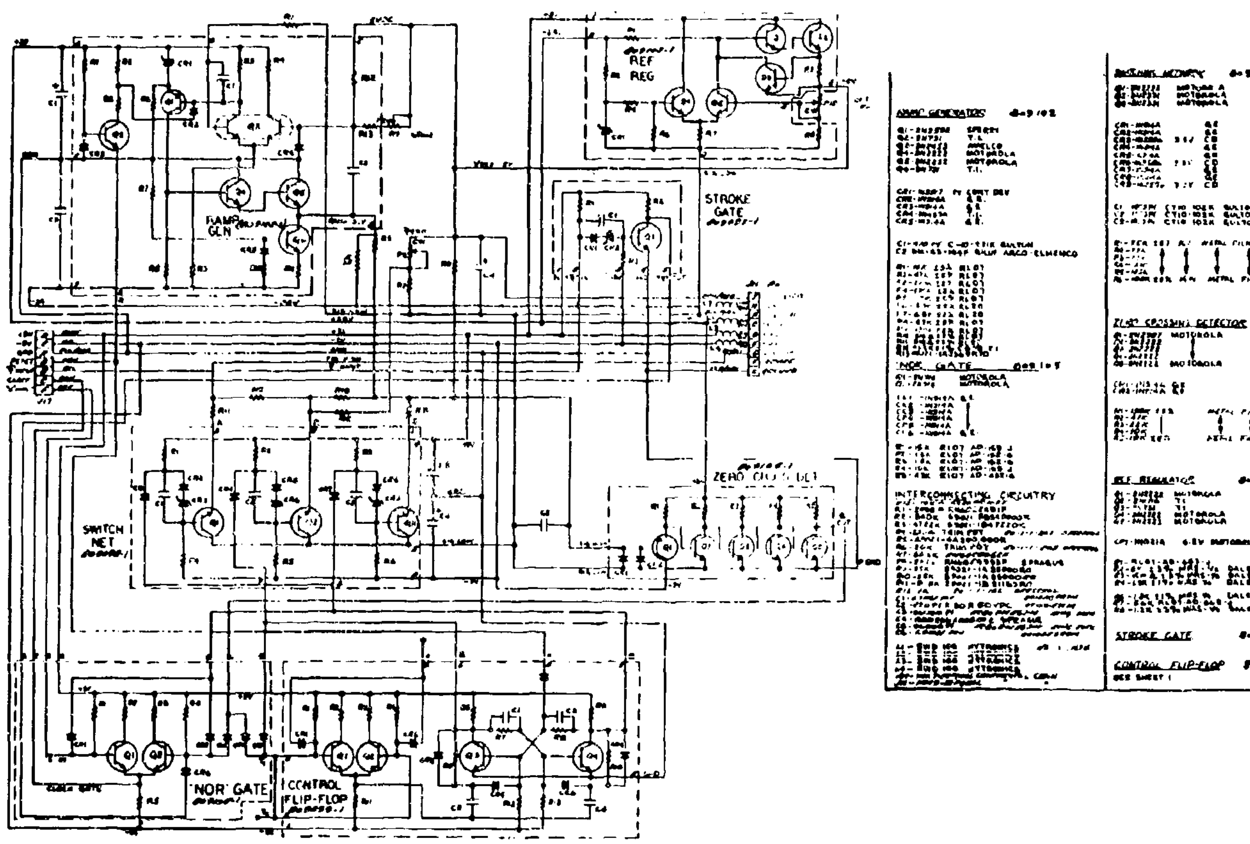
809051 | 809121
NEXT ASSY | USED ON

WIRING DIAGRAM SCHEMATIC
FREQUENCY TO DIRECT CURRENT

70210 D X 809051

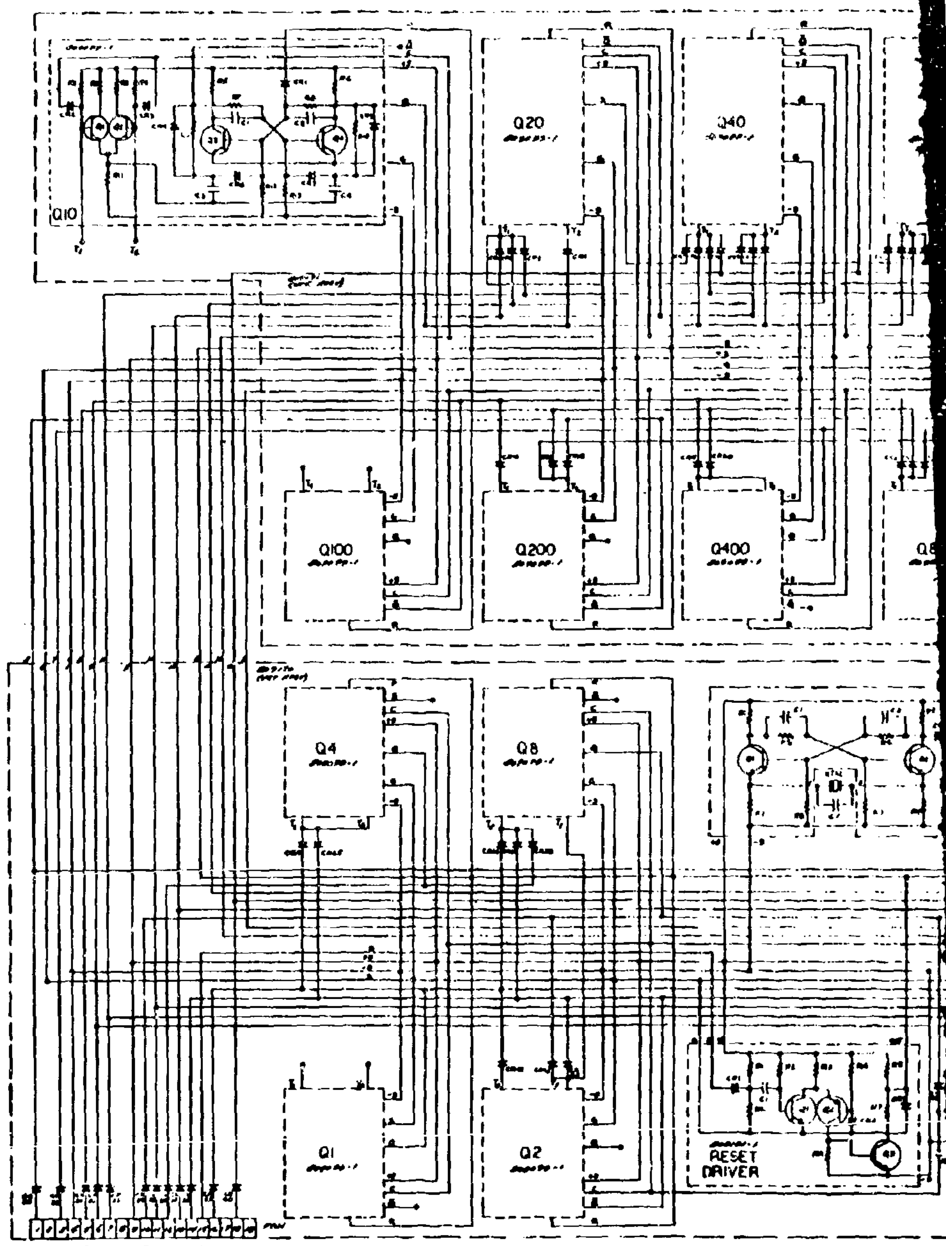
B

X 809051



ANALOG SECTION

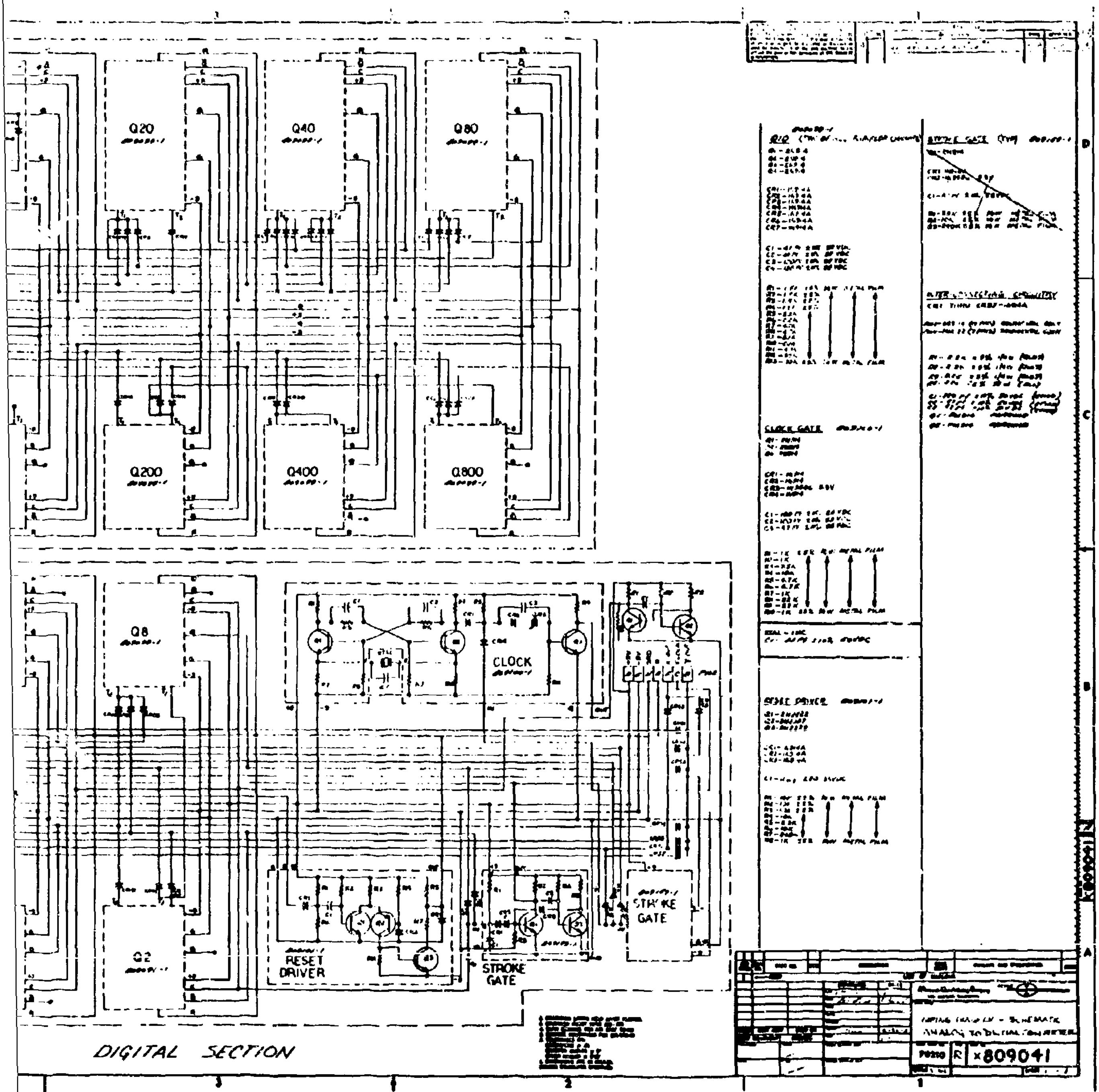
A



DIGITAL SECTION

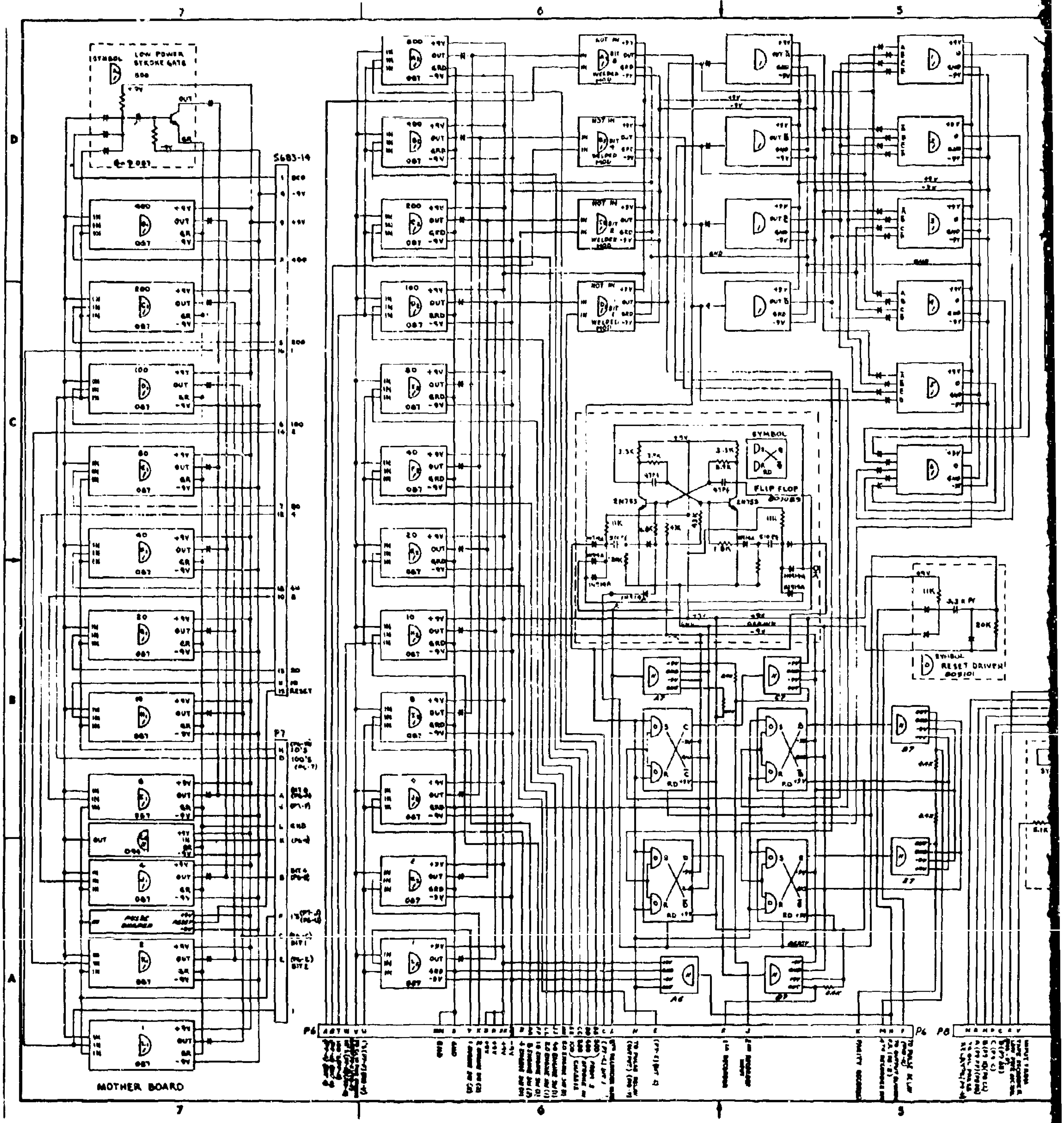
X 809041

B



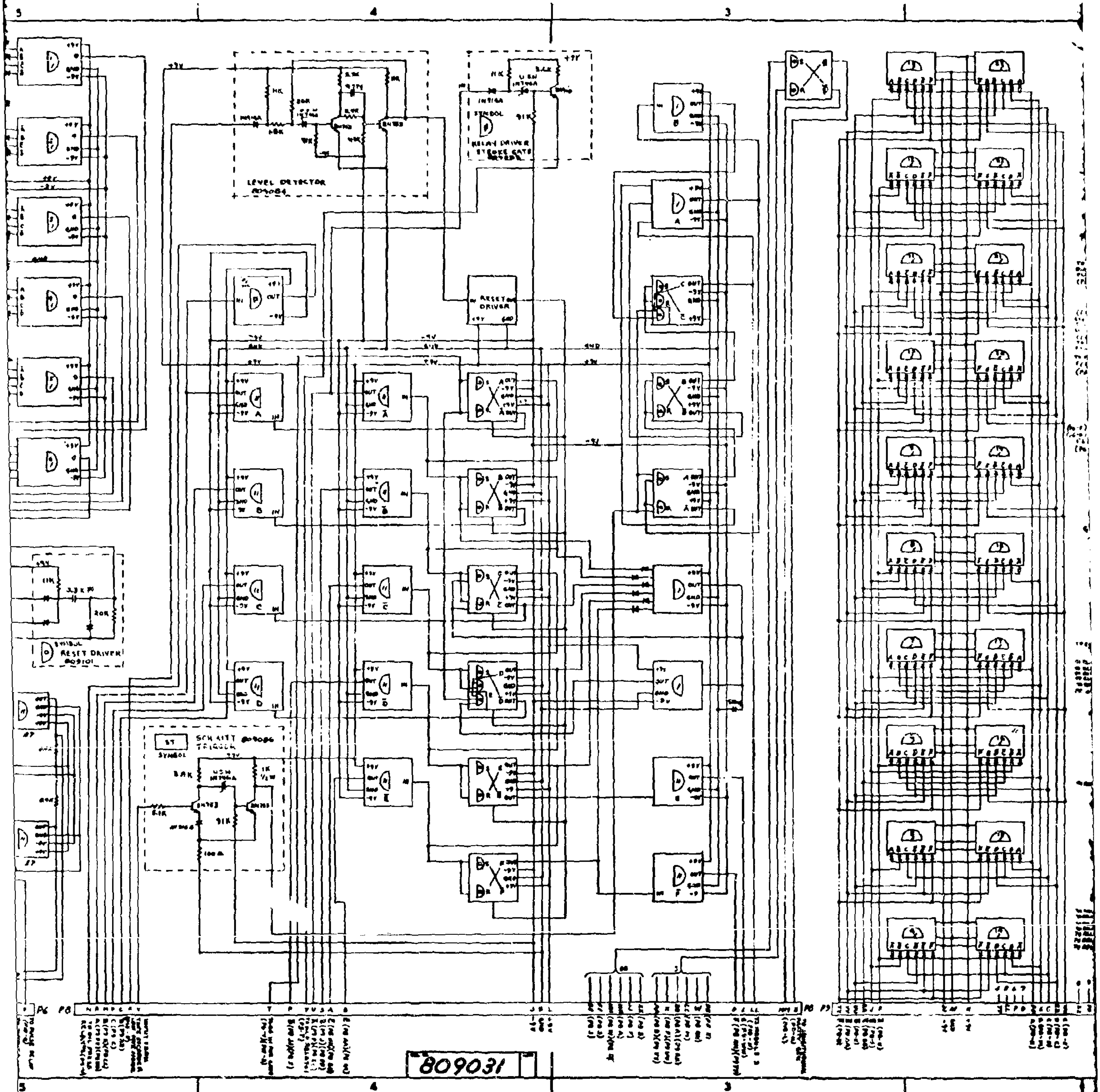
Q20
Q40
Q80
Q200
Q400
Q800
Q8
Q2
CLOCK
RESET
DRIVER
STROKE
GATE
STROKE
GATE
DIGITAL SECTION
CLOCK GATE
RESET DRIVER
STROKE GATE
ANALOG TO DIGITAL CONVERTER
R
x809041

C



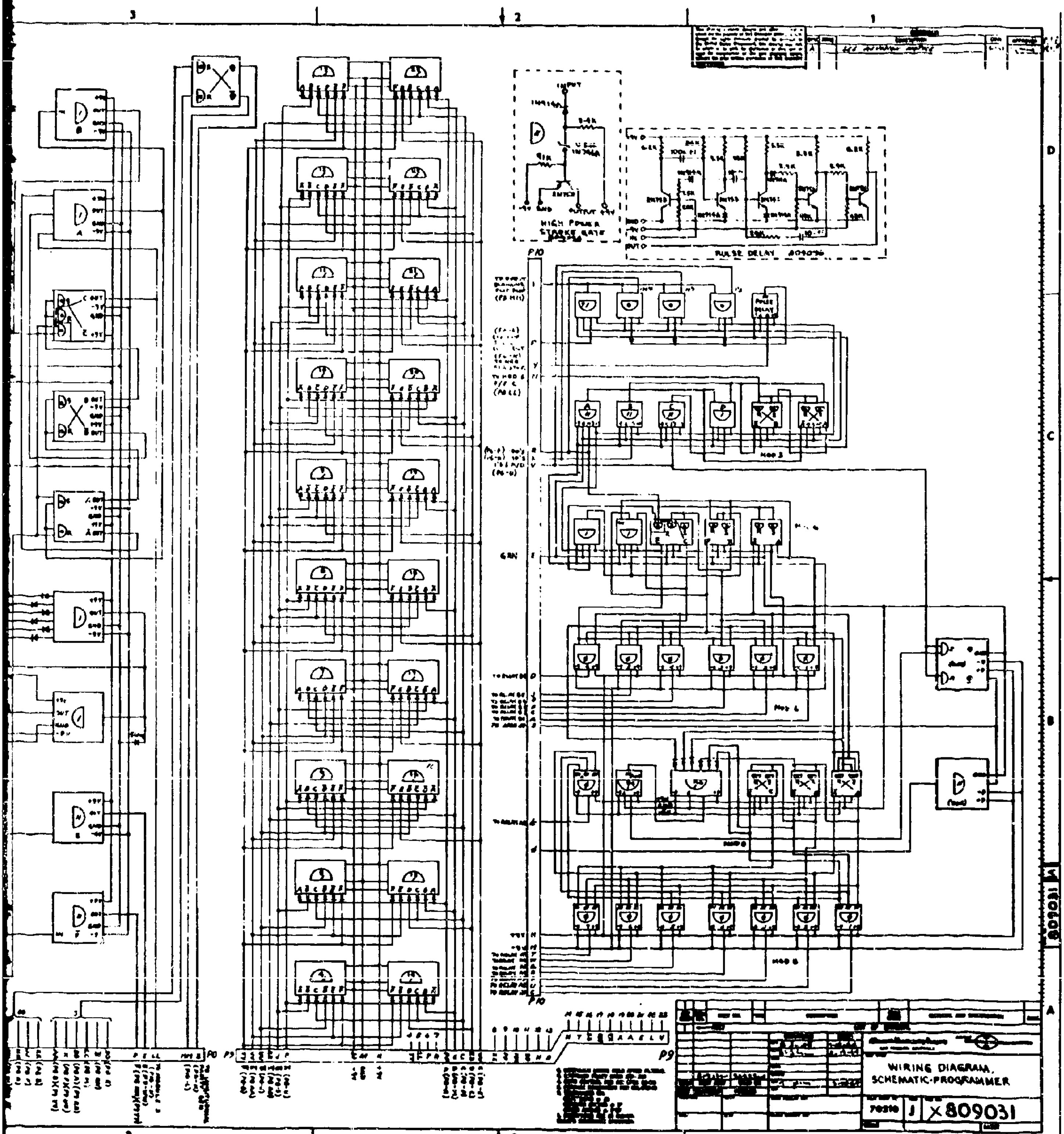
LOW POWER STROKE GATE
S683-14
SYMBOL
FLIP FLOP
RESET DRIVER
MOTHER BOARD

A



LEVEL DETECTOR 809084
RELAY DRIVER
RESET DRIVER
SYMBOL RESET DRIVER 809101
SCHMITT TRIGGER 809086
809031

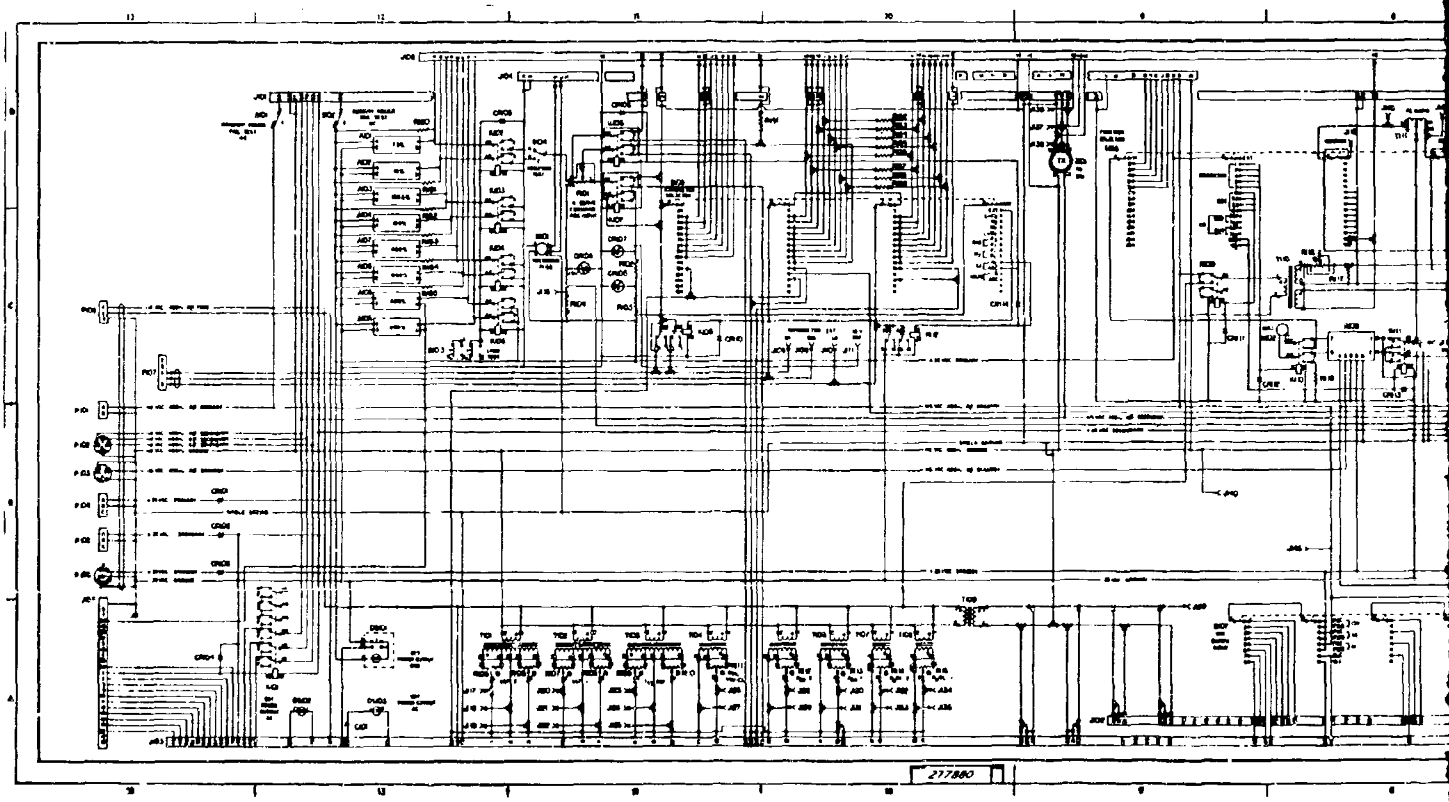
B


HIGH POWER STROBE GATE
PULSE DELAY 809096
WIRING DIAGRAM, SCHEMATIC-PROGRAMMER
X809031

Schematic 898-308 for the Data Recorder System EMR-2, P/N 538956, is available from Elgin Research and Development, Division of Elgin National Watch Company, Elgin, Illinois, Drawing 898-308 Project 20898.

APPENDIX III

CIRCUIT SCHEMATICS FOR F-105D AND F-4C SYSTEM GROUND CALIBRATOR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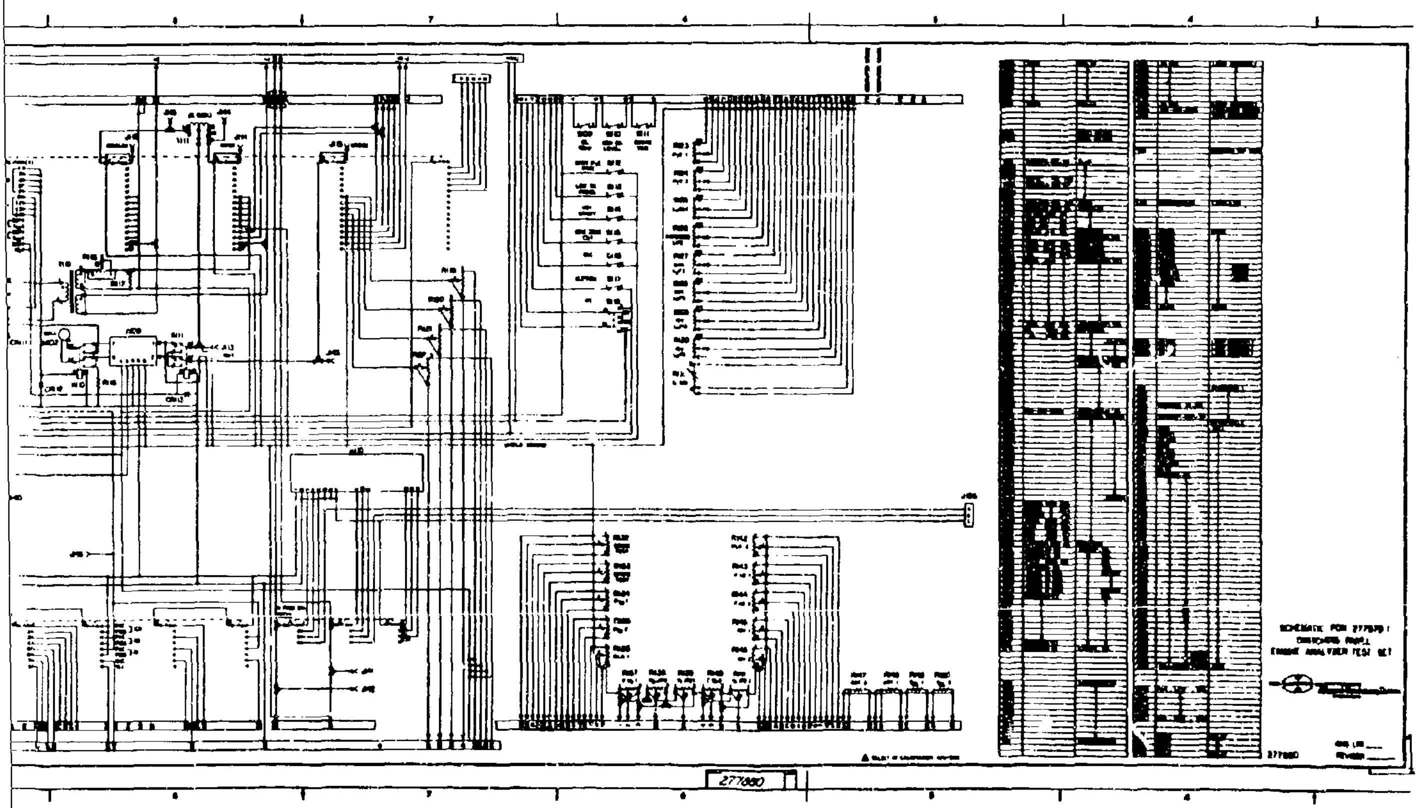

B

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	2b. GROUP NA

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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report May 1963-July 1965

5. AUTHOR(S) (Last name, first name, initial)

HARRIS, WHITE J.

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d. Item No. 10		

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11. SUPPLEMENTARY NOTES None	12. SPONSORING MILITARY ACTIVITY Systems Engineering Group Aeronautical Systems Division AF Systems Command, Wright-Patterson AFB, Ohio

13. ABSTRACT

This report describes Turbojet Engine Analyzer System as developed for application to J75-19W and J79-15 engines. Included are descriptions and design details of each major system component. The theory of operation, the modular breakdown, the self-test provisions, and the adjustments of the components are presented. Similar material is included on the System Ground Calibration, a piece of ground support equipment.

The system is designed to monitor, analyze, and assess complete turbojet engine performance during ground and flight operations for the purpose of detecting required maintenance and diagnosing incipient or actual failures.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Engine Analyzer						
Jet Engine Analyzer						
Engine Performance Computation						
Airborne Data Acquisition						
Engine Data Processing						

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